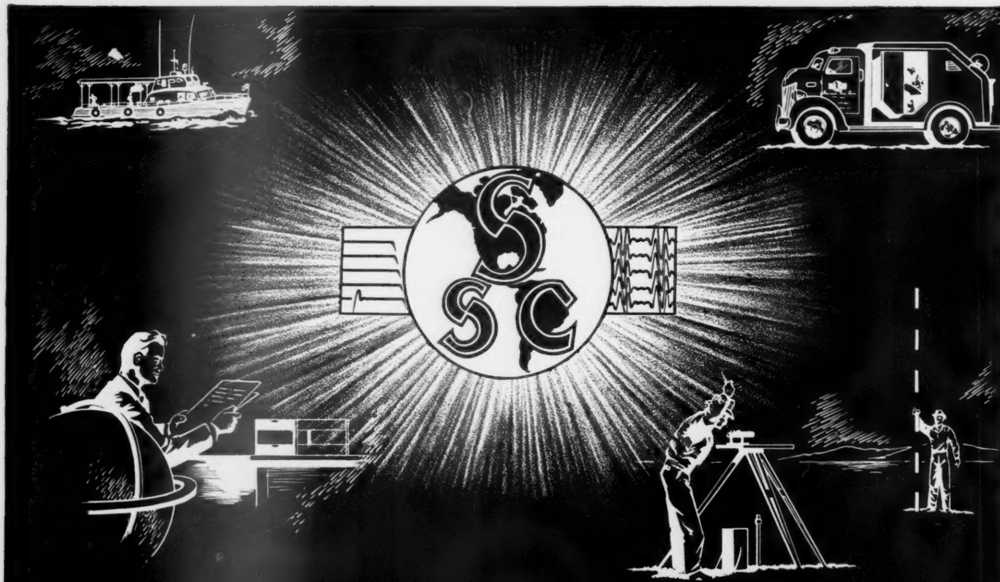
0&Rq/x1/24-1

Volume 33 SEPTEMBER, 1949 Number 9

BULLETIN
of the
American Association *of* Petroleum Geologists

CONTENTS



BULLETIN

of the

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

OFFICE OF PUBLICATION, CHESTNUT-SMITH BUILDING, TULSA, OKLAHOMA

THE BULLETIN is published by the Association on the 15th of each month.

EDITORIAL AND PUBLICATION OFFICE AND ASSOCIATION HEADQUARTERS, Chestnut-Smith Building, 624 South Cheyenne Avenue, Tulsa, Oklahoma. Post Office, Box 979, Tulsa 1. Cable address: AAPEGOL.

SUBSCRIPTION PRICE to non-members is $15 per year (separate numbers, $1.50), prepaid to addresses in the United States; outside the United States, $15.40.

CLAIMS FOR NON-RECEIPT must be sent within 3 months of date of publication, to be filled gratis.

BACK NUMBERS, if available, may be ordered from Headquarters. Price list on request.

	Mem.	*Non-Mem.*
Cloth-bound Bulletin, Vols. 13 (1929)-15 (1931) incl., each	$5.00	$6.00

SPECIAL PUBLICATIONS	*Mem.*	*Non-Mem.*
1934. Problems Petroleum Geology	4.00	5.00
1936. Geology of Tampico Region	3.50	4.50
1938. Miocene Strat. California ..	4.50	5.00
1941. Future Oil Provinces	1.00	1.50
1944. Tectonic Map of U.S.	2.00	2.00
1946. Directory Geol. Material	.75	.75
1947. Comprehensive Index '17-'45	3.00	4.00
1948. Typ. Amer. Oil Fields, III	3.50	4.50
1948. Appalachian Ordovician Sym.	1.50	2.00
1949. Stratigraphy Alberta Basin .	1.00	1.50
1949. Directory College Geol. Depts.	1.50	1.50

Communications about the Bulletin, manuscripts, editorial matters, subscriptions, special rates to public and university libraries, publications, membership, change of address, advertising rates, and other Association business should be addressed to

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, INC.

J. P. D. HULL, BUSINESS MANAGER
ELMER W. ELLSWORTH, ASSISTANT BUSINESS MANAGER
BOX 979, TULSA 1, OKLAHOMA

Entered as second-class matter at the Post Office at Tulsa, Oklahoma, and at the Post Office at Menasha, Wisconsin, under the Act of March 3, 1879. Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized March 9, 1913.

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, INC.

Organized at Tulsa, Oklahoma, February 10, 1917, as the Southwestern Association of Petroleum Geologists. Present name adopted February 16, 1918. Incorporated in Colorado, April 23, 1924. Domesticated in Oklahoma, February 9, 1925.

OFFICERS FOR THE YEAR ENDING APRIL, 1950

C. W. TOMLINSON, *President*, Ardmore, Oklahoma
THEO. A. LINK, *Vice-President*, Calgary, Alberta
H. N. TOLER, *Secretary-Treasurer*, Jackson, Mississippi
ALFRED H. BELL, *Editor*, Urbana, Illinois

The foregoing officers and the *Past-President*, PAUL WEAVER, Houston, Texas, constitute the Executive Committee

DISTRICT REPRESENTATIVES (Terms expire after annual meetings of years shown in parentheses)

Amarillo: R. B. Totten (50), Amarillo, Tex.

Appalachian: R. Douglas Rogers, Jr. (51), Parkersburg, W.Va.

Canada: J. B. Webb (51), Calgary, Alberta

Capital: W. G. Pierce (50), Washington, D.C.

Corpus Christi: O. G. McClain (51), Corpus Christi, Tex.

Dallas: John W. Clark (50), R. A. Stehr (51), Dallas, Tex.

East Oklahoma: Ralph A. Brant (50), Tulsa; Dallas, Tex. Charles (50), Bartlesville; L. E. Fitts, Jr. (51), A. N. Murray (51), Tulsa

Fort Worth: J. B. Lovejoy (51), Fort Worth, Tex.

Great Lakes: J. A. Brown (50), Evansville, Ind.; C. E. Brehm (51), Mt. Vernon, Ill.

Houston: Ralph B. Cantrell (50), Robert B. Mitchell (50), A. L. Selig (50), W. Z. Burkhead (51), H. C. Ferguson (51), G. J. Smith (51), Houston, Tex.

Michigan: R. B. Newcombe (51), Grand Rapids

New Mexico: Noel R. Lamb (51), Artesia

New York: Walter K. Link (50); Bruno O. Winkler (51), *New York City*

Pacific Coast: Frank B. Carter (50), Los Angeles; Thomas J. Fitzgerald (50), Bakersfield; Allison J. Solari (50), San Francisco; Peter H. Gardett (51), Manley L. Natland (51), Los Angeles; Aden W. Hughes (51), Orcutt; R. D. Patterson (51), Bakersfield, Calif.

Rocky Mountains: E. J. Boos (50), Casper, Wyo.; Kirk C. Forcade (50), Denver, Colo.; D. E. Edstrom (51), Casper, Wyo.

Shreveport: C. N. Valerius (51), Shreveport, La.

South America: Walter M. Chappell (50), Bogota, Colombia; Karl F. Dallmus (51), Maracaibo, Venezuela

Southeast Gulf: David C. Harrell (51), Jackson, Miss.

Southern Louisiana: D. D. Utterback (51), New Orleans

So. Permian Basin: Max David (50), Midland, Tex.; Vincent C. Perini (50), Abilene, Tex.; W. H. Conkling (51), Midland, Tex.

South Texas: M. J. Moore (50), W. W. Hammond (51), San Antonio

Tyler: J. S. Hudnall (51), Tyler, Tex.

West Oklahoma: Jerome M. Westheimer (50), Ardmore; Harold J. Kleen (51), Oklahoma City

Wichita: Jack H. Heathman (50), Frank A. Oyster (51), Wichita, Kan.

Wichita Falls: James E. Wilson (50), Wichita Falls, Tex.

DIVISION REPRESENTATIVES

Paleontology and Mineralogy: Henryk B. Stenzel (50), Austin, Texas; Cecil G. Lalicker (50), Lawrence, Kansas

PACIFIC SECTION (Chartered, March, 1925)

CLIFTON W. JOHNSON, *President*, Richfield Oil Corpn., Room 430, Richfield Bldg., Los Angeles 13, California
JOHN E. KILKENNY, *Vice-President*, C.C.M. Oil Co., 4549 Produce Plaza W., Los Angeles 11, California
HAROLD E. RADER, *Secretary-Treasurer*, Standard Oil Co., Box 2437, Terminal Annex, Los Angeles 54, California
Membership restricted to members of the Association in good standing, residing in Pacific Coast states. Dues: $2.00 per year.

EASTERN SECTION (Chartered, April, 1946)

HOLLIS D. HEDBERG, *President*, Gulf Oil Corporation, 17 Battery Place, New York, N.Y.
G. F. KAUFMANN, *Secretary*, Standard Vacuum Oil Company, Room 1556, 26 Broadway, New York, N.Y.
Membership restricted to members of the Association in good standing, residing in New York district.

DIVISION OF PALEONTOLOGY AND MINERALOGY
SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

(Organized, March, 1927; affiliated, March, 1928; chartered, technical division, April, 1930)
HENRYK B. STENZEL, *President*, Bureau of Economic Geology, Austin 12, Texas
CECIL G. LALICKER, *Secretary-Treasurer*, University of Kansas, Lawrence, Kansas

SEND DUES, SUBSCRIPTIONS AND ORDERS FOR BACK NUMBERS TO BOX 979, TULSA 1, OKLAHOMA

The society and the Paleontological Society jointly issue six times a year the *Journal of Paleontology*, J. Marvin Weller, University of Chicago, Chicago 37, Illinois, and A. S. Warthin, Vassar College, Poughkeepsie, New York, editors: subscription. $6.00. The *Journal of Sedimentary Petrology*, W. H. Twenhofel, editor, and J. L. Hough, managing editor, University of Illinois, Urbana, Illinois, is issued three times a year: subscription, $3.00. Single copies, *Journal of Paleontology*, $2.00; *Journal of Sedimentary Petrology*, $1.75. Society dues: with *Jour. Pal.*, $5.00; with *Jour. Sed. Petrology*, $3.00; with both, $8.00 per year.

AFFILIATED SOCIETIES (Dates of affiliation in parentheses)

Abilene Geological Society, Abilene, Texas (47). C. S. Noland, Secy., Skelly Oil Company
Alberta Society of Petroleum Geologists, Calgary, Alberta (31). F. A. McKinnon, Secy., Royalite Oil Co., ltd.
Appalachian Geological Society, Charleston, W.Va. (31). W. T. Ziebold, Secy., Spartan Gas Company, Box 766
Ardmore Geological Society, Ardmore, Oklahoma (36). Frank Millard, Secy., Schlumberger Well Surveying Corp., Box 747
Associacao Brasileria de Petroleo, Salvador, Bahia, Brazil (47)
Corpus Christi Geological Society, Corpus Christi, Texas (43). H. W. Volk, Jr., Secy., Tide Water Associated Oil Co.
Dallas Geological Society, Dallas, Texas (35). Gilbert P. Moore, Secy., Consulting, 501 Continental Building
East Texas Geological Society, Tyler, Texas (32). Rosella L. Bunch, Secy., Shell Oil Company, Inc., Box 2037
Fort Worth Geological Society, Fort Worth, Texas (31). Thomas Nichols, Secy., Rowan Oil Company, Commercial Standard Bldg.
Houston Geological Society, Houston, Texas (32). James H. McGuirt, Secy., Tide Water Associated Oil Company
Illinois Geological Society (39). Lloyd A. Harris, Secy., Carter Oil Company, Box 568, Mattoon, Ill.
Indiana-Kentucky Geological Society (38). J. B. Vaughan, Secy., Ashland Oil and Refg. Co., Henderson, Ky.
Kansas Geological Society, Wichita, Kansas (31). Victor F. Reiserer, Secy., Superior Oil Company. 510 K. F. H. Bldg.
Michigan Geological Society, Mt. Pleasant, Michigan (37). Jack Mortenson, Secy., Sohio Oil Company, 601 S. Main St.
Mississippi Geological Society, Box 2253, West Jackson, Miss. (41). F. T. Holden, Secy., Carter Oil Company, Box 1490
New Orleans Geological Society, New Orleans, La. (43). H. A. Nystrom, Secy., Schlumberger Well Surveying Corporation
North Texas Geological Society, Wichita Falls, Texas (38). Walter L. Ammon, Secy., Stanolind Oil and Gas Co., Box 1680
Oklahoma City Geological Society, Oklahoma City, Okla. (31). L. W. Curtis, Secy., Sohio Petroleum Company
Panhandle Geological Society, Amarillo, Texas (32). Robert B. Totten, Secy., Sun Oil Company, Box 46
Shawnee Geological Society, Shawnee, Oklahoma (31). Marcelle Mousley, Secy., Atlantic Refining Company, Box 169
Shreveport Geological Society, Shreveport, La. (32). Charles A. Hickcox, Secy., Centenary College, Box 750
Society of Exploration Geophysicists (32). K. E. Burg, Secy., Geophysical Service, Inc., Dallas, Tex.
South Louisiana Geological Society, Lake Charles, La. (37). James M. Whatley, Secy., Union Sulphur Company
South Texas Geological Society, San Antonio (49). L. H. Haring, Jr., Secy., Stanolind Oil and Gas Co.
Southeastern Geological Society, Tallahassee, Fla. (44). Albert C. Raasch, Secy., Humble Oil and Refining Co., Box 506
Tulsa Geological Society, Tulsa, Oklahoma (31). Mary Whitehead, Secy., Stanolind Oil and Gas Co., Box 591
West Texas Geological Society, Midland, Texas (38). J. A. Rogers, Secy., Box 1595
Wyoming Geological Association, Box 545, Casper (45). J. B. Headley, Jr., Secy., Atlantic Refg. Co.
Yellowstone-Bighorn Research Association, Inc. (44). W. T. Thom, Jr., Secy., Princeton, N.J.

Bulletin Advertisers

PROFESSIONAL CARDS

GEOLOGICAL AND GEOPHYSICAL SOCIETIES

Articles for October *Bulletin*

Evolution of Thought on Structure of Middle and Southern Appalachians — By John Rodgers
Regional Aspects of Cambrian and Ordovician Subsurface Stratigraphy in Kentucky — By Louise Barton Freeman
Subsurface Upper Devonian Sections in Southwestern Pennsylvania — By Robert E. Bayles
Petrology and Paleogeography of Greenbrier Formation — By Gordon Rittenhouse
Mayfield Pool, Cuyahoga County, Ohio — By Howard E. Rothrock
Geologic Implications of Aeromagnetic Survey of Clearfield-Philipsburg Area, Pennsylvania — By H. R. Joesting, Fred Keller, Jr., and Elizabeth King

Volume 33 Number 9

BULLETIN
of the
AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

SEPTEMBER, 1949

INTERPRETATIONS OF FOOTHILLS STRUCTURES, ALBERTA, CANADA[1]

THEODORE A. LINK[2]
Toronto, Ontario, and Calgary, Alberta

ABSTRACT

During the last decade geophysical exploration in the Foothills area of Alberta has aided considerably in arriving at rough approximations, and in some cases fairly reliable data, with respect to the nature of the structural conditions above and beneath major sole faults. The compilation of structural cross sections on the basis of such surveys, plus knowledge derived from previous subsurface drilling and surface geology, are the main theme of this contribution.

Several examples of structures mapped and drilled are given, together with a hypothetical case wherein the difficulties of interpretations are discussed. The structures described are Turner Valley, Highwood uplift, Jumping Pound, Brazeau uplift, Stolberg, Coalspur, Savannah Creek, and the hypothetical Alpha structure.

INTRODUCTION

The tectonic forces which gave rise to the building of the Rocky Mountains and Foothills of western Canada were operative from west to east. There appear to be contradictions to this statement, but when the data are fully studied and analyzed, they generally fit into the picture and thus substantiate the original contention. Furthermore, the intensity of the resultant deformation decreases gradually from west to east, so that the less complicated structures are at the eastern edge of the Foothills. A logical corollary to this is the observed fact that folded faults and folded overthrust sheets are more common in the interior or western part of the Foothills nearer the mountains.

The construction of idealized cross sections through the Foothills is, in some respects, an enjoyable pastime, but detailed cross sections which indicate ultimate depths to prospective oil zones is another matter, and these must be attempted

[1] Read before the Association at Los Angeles, March 26, 1947, through the courtesy of O. B. Hopkins, vice-president of the Imperial Oil Limited. The writer is indebted to the various members of the geological and geophysical staff of the Imperial Oil Limited at Calgary, Alberta, as indicated on the figures and in the text, for their respective contributions. Manuscript received, March 14, 1949.

[2] Geologist, Room 3100, 25 King Street West, Toronto, Ontario, and 810A First Street West, Calgary, Alberta, Canada.

by the petroleum geologist. The object of this contribution is to present illustrations showing results of some of the recent findings in the Foothills on the basis of surface geology, seismic-reflection surveys, and subsequent deep drilling.

EXPLORATION IN FOOTHILLS

Since the discovery of large volumes of gas and distillate in 1924 in the Turner Valley field, exploration in the Foothills belt of Alberta has varied in intensity from year to year, dependent on geologic thinking and results obtained. The

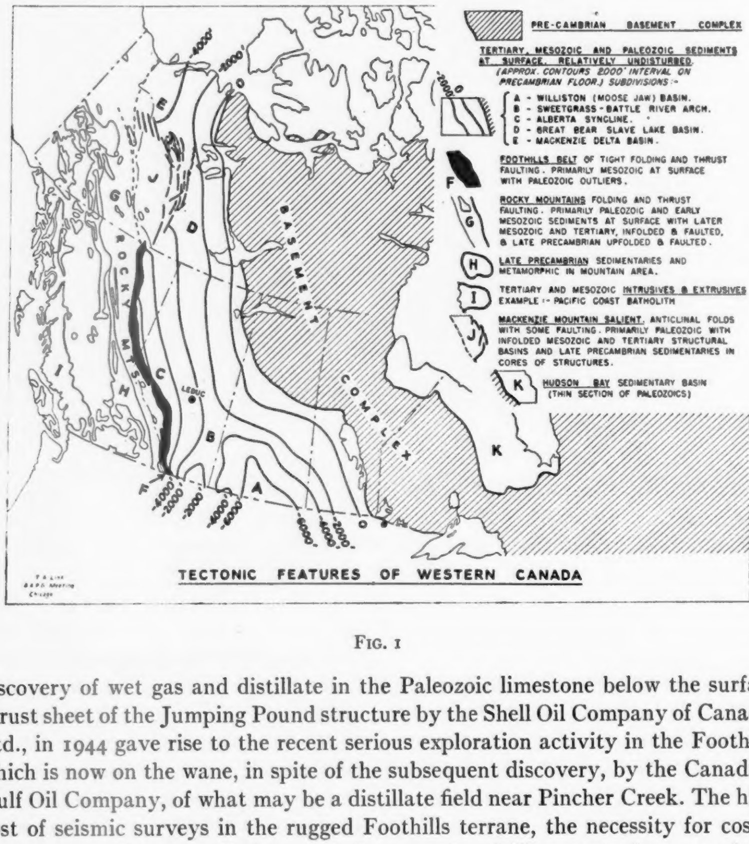


FIG. 1

discovery of wet gas and distillate in the Paleozoic limestone below the surface thrust sheet of the Jumping Pound structure by the Shell Oil Company of Canada, Ltd., in 1944 gave rise to the recent serious exploration activity in the Foothills which is now on the wane, in spite of the subsequent discovery, by the Canadian Gulf Oil Company, of what may be a distillate field near Pincher Creek. The high cost of seismic surveys in the rugged Foothills terrane, the necessity for costly road construction to well sites, and the excessive drilling costs, because of the great depths of the prospective oil zones, call for large expenditures of money; consequently, some of the more recent wildcats drilled in the Foothills belt of Alberta were joint affairs wherein two, and in some instances as many as five,

oil companies combined forces and resources to drill such tests. Since 1942, 18 holes have been drilled in the Foothills, based on geologic and seismic-reflection work, but to date only the Jumping Pound and Pincher Creek structures appear to justify hope that these discoveries may lead to something commercial, like the west-flank oil accumulation at Turner Valley. The total amount of money expended by the industry on the Jumping Pound structure alone, for surface geologic, seismic, and gravity-meter surveys, leases, and drilling is probably more than $2,000,000, the largest part of which was expended by the Shell Oil Company of Canada. The Pincher Creek project has promise of similar expendi-

FIG. 2

tures. Obviously the recent oil discoveries at Leduc and Redwater, at relatively shallow depths, will exert a retarding influence on Foothills exploration for some time, unless markets for natural gas are established.

TURNER VALLEY

The most logical Foothills structure to consider first is Turner Valley, which has now been so thoroughly drilled that the nature of the structure and the oil and gas accumulation is fairly well established. On the index map (Fig. 2) are shown the relative positions of the Turner Valley, Jumping Pound, Stolberg, Brazeau, Coalspur, Savannah Creek, Muskeg, and Pincher Creek structures.

Figure 3 is a structure-contour map of Turner Valley (contour interval 1,000

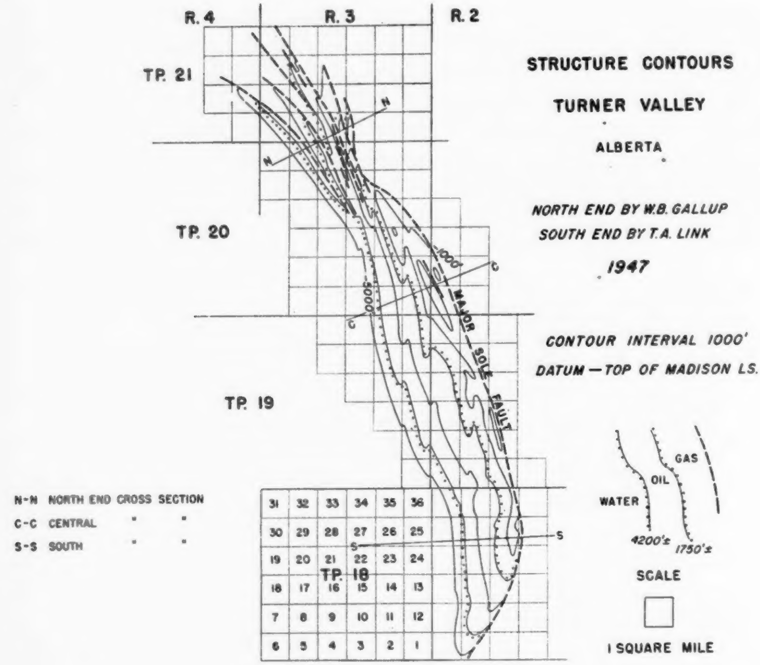


FIG. 3

feet) showing the gas cap, oil area, and edge-water zone. To be noted is the relatively simple nature of the structure at the top of the Madison limestone in the central and south parts, and the more recently developed northern extension which is more complicated by faults. Near the crest, inside the surface rim rock, the structure is also much more complicated above the Paleozoic limestone throughout the field (Figs. 4, 5, and 6). The structural relief or effective closure, from the highest known contour on the gas cap to the water-oil boundary, is slightly more than 5,000 feet.

The writer desires to withdraw his interpretation of the major sole fault of Turner Valley in his contributions of 1934 and 1935[3] wherein the upthrown mass of the fault was interpreted as a "decapitated anticline." (This retraction should have been made years ago.) Contrary evidence was found by west-flank drilling after the discovery of crude oil, and by several deep tests through the sole fault near the center of the field. However, there is still the possibility, adhered to by

[3] Theodore A. Link and P. D. Moore, "Structure of Turner Valley Gas and Oil Field, Alberta," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 18, No. 11 (November, 1934), pp. 1417–53.
Theodore A. Link, "Types of Foothills Structures of Alberta, Canada," *ibid.*, Vol. 19, No. 10 (October, 1935), pp. 1427–71.

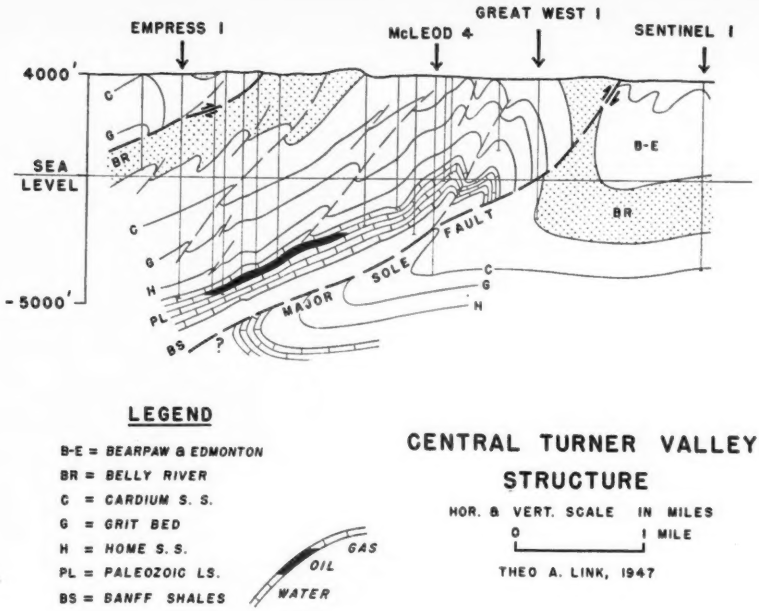

EMPRESS I
McLEOD 4
GREAT WEST I
SENTINEL I
4000'
SEA LEVEL
-5000'
B-E
BR
C
G
H
PL
BS
MAJOR SOLE FAULT
LEGEND
B-E = BEARPAW & EDMONTON
BR = BELLY RIVER
C = CARDIUM S. S.
G = GRIT BED
H = HOME S. S.
PL = PALEOZOIC LS.
BS = BANFF SHALES
GAS
OIL
WATER
CENTRAL TURNER VALLEY STRUCTURE
HOR. & VERT. SCALE IN MILES
0
1 MILE
THEO A. LINK, 1947

FIG. 4

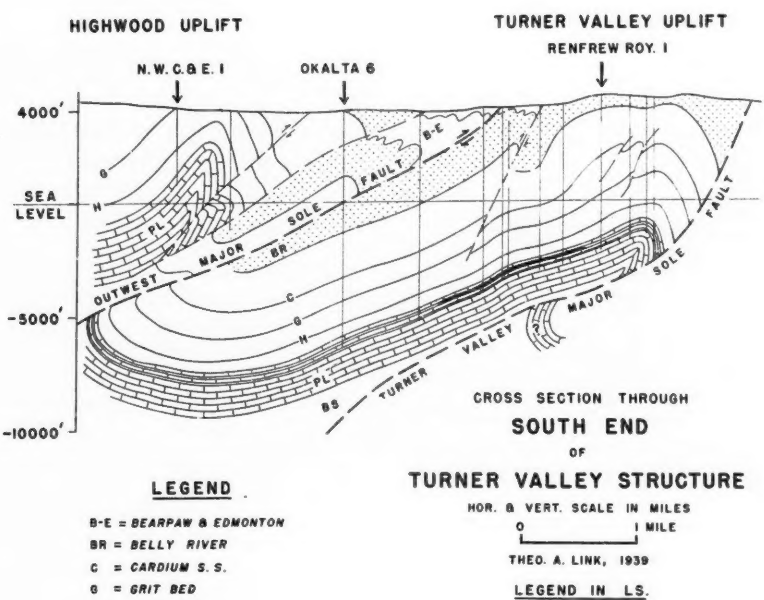

HIGHWOOD UPLIFT
TURNER VALLEY UPLIFT
N.W. C.& E. I
OKALTA 6
RENFREW ROY. I
4000'
SEA LEVEL
-5000'
-10000'
B-E
BR
G
H
C
PL
BS
MAJOR SOLE FAULT
OUTWEST
TURNER VALLEY MAJOR SOLE FAULT
CROSS SECTION THROUGH
SOUTH END
OF
TURNER VALLEY STRUCTURE
HOR. & VERT. SCALE IN MILES
0
1 MILE
THEO. A. LINK, 1939
LEGEND IN LS.
GAS
OIL
WATER
LEGEND
B-E = BEARPAW & EDMONTON
BR = BELLY RIVER
C = CARDIUM S. S.
G = GRIT BED
H = HOME S. S.
PL = PALEOZOIC LS.
BS = BANFF SH.

FIG. 5

some, that deeper drilling still farther down the west flank and through the fault could validate the "decapitated" interpretation. Conditions as observed at the Savannah Creek structure support such a possibility. Nevertheless, with the data available, the interpretations here submitted are preferred by the writer.

Figure 4 is a cross section through the central and highest part of the structure. The major sole fault has been fairly well established considerably below the west

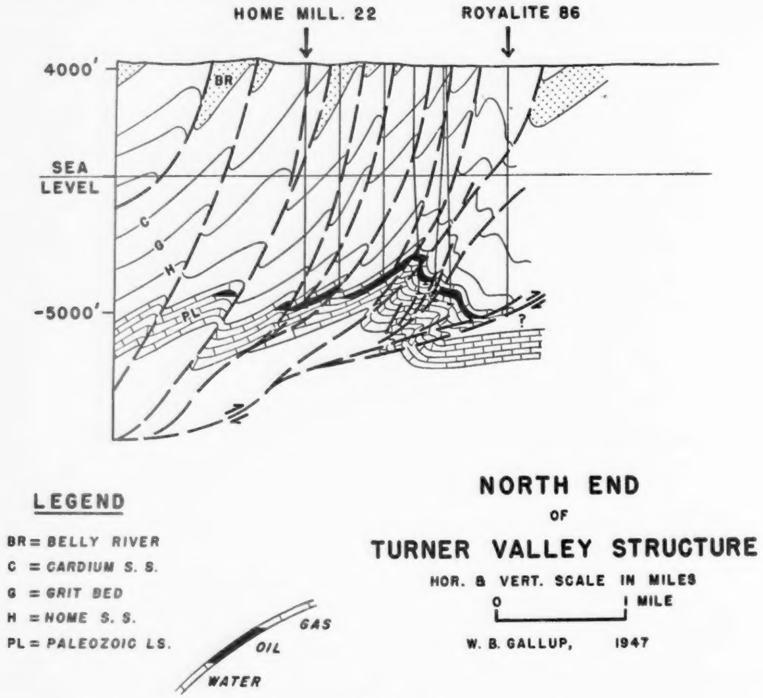


FIG. 6

flank by tests drilled through it. Little is known about the downthrown part of the Turner Valley structure in this section of the field, as no hole has been drilled deep enough to reach the Paleozoic limestone the second time; however, north of this cross section, Royalite No. 73 established the presence of the limestone on the downthrown side at a depth of 7,630 feet, and this may renew efforts to establish production from such a downthrown block.

Figure 5 is a cross section through the south end of the field illustrating a more simple type of structure than the central cross section. To be noted is the relationship between Turner Valley and the west-lying Highwood uplift, which is another overthrust sheet involving the Paleozoic limestone but containing water and dry

gas near the top, though this mass is much higher structurally than Turner Valley. The sole fault underlying this thrust sheet is termed the "Out-West fault."

Figure 6 is a typical cross section through the north end of Turner Valley which shows clearly the numerous faults cutting the Paleozoic limestone and the resultant much more complicated nature of the structure. To be noted in particular is the presence of limestone fault-blocks on the east flank. These contain oil at a level lower than the water-oil contact on the west flank. This, coupled with

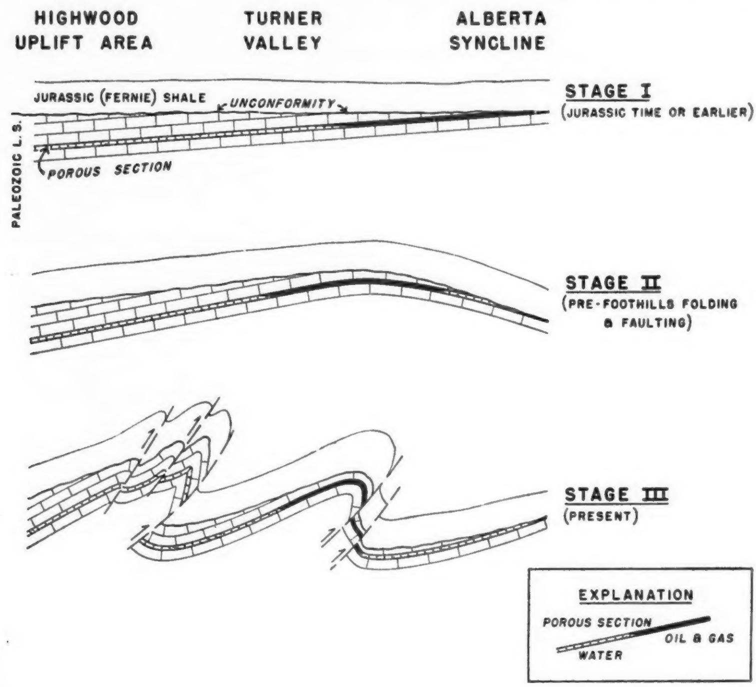


FIG. 7

the water in the west-lying Highwood uplift at a much higher level, as shown in Figure 5, suggests that the oil and gas accumulations and water segregation took place previous to the development of the thrust fault, as suggested in Figure 7, in which are shown the probable stages of the growth of the Turner Valley structure and the related Highwood uplift. It is not necessary to postulate an anticlinal uplift to effect the segregation of the oil, gas, and water as shown in Stage II. The same results could have been obtained under the assumption that the segregation took place in a west-dip stratigraphic-trap accumulation, such as a coral reef, or against the unconformity on the east, without going through the

anticlinal stage. However, the history as depicted in Figure 7 is regarded as more probable. It is now believed that the porosity of the producing zones in Turner Valley is in reef limestones of the biostrome rather than the bioherm type.

With this brief outline of Turner Valley in mind, some of the more recently drilled Alberta Foothills structures are described. On only two of these has oil been found, but knowledge of these structures may be helpful if the exploration pendulum should swing back to the Foothills.

JUMPING POUND STRUCTURE

The surface expression of the Jumping Pound structure, an outer Foothills fold 20 miles north of Turner Valley, is almost a duplicate of the latter. Approxi-

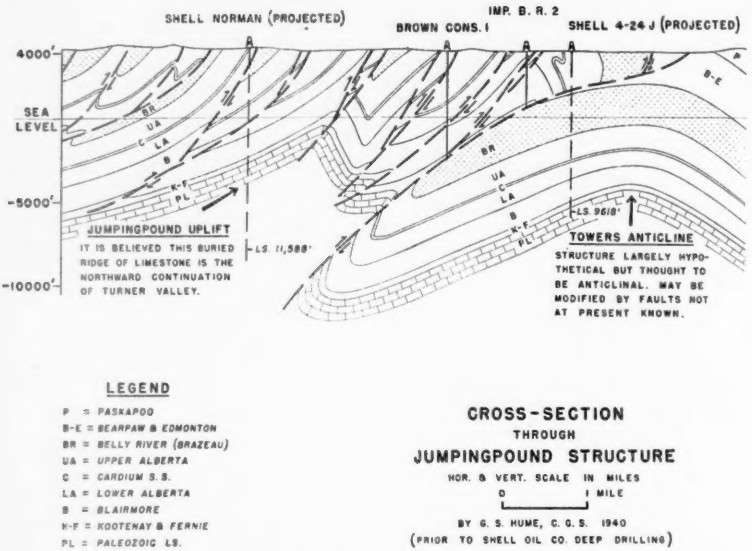


FIG. 8

mately 20 years ago the Imperial Oil Limited drilled two tests through a shallow-depth thrust fault, and abandoned the prospect because the probable depth to the Paleozoic limestone was estimated at 10,000 feet—somewhat too deep for the cable tools which were then being used. Figure 8 is a cross section of the Jumping Pound structure as published by G. S. Hume of the Canadian Geological Survey in 1940, showing the position of one of these Imperial-drilled locations and that of the Brown Oil Consolidated. A seismic profile was run by the Heiland Research Corporation for the Brown Oil Company over this structure during 1940, and on the basis of further seismic work, and possibly Hume's cross section,[4]

[4] G. S. Hume, "The Structure and Oil Prospects of the Foothills of Alberta between Highwood and Bow Rivers," *Canada Geol. Survey Paper 40–8* (1940).

the Shell Oil Company of Canada drilled two deep tests during the years 1942–1944. The first of these, the Shell's Norman 1, superimposed on this illustration (Fig. 8), and shown at the extreme left, encountered water in the porous part of the Paleozoic limestone which was reached at a depth of 11,588 feet, much lower than expected on this cross section. The second test, the Shell's 4-24-J, projected and superimposed at the right on the cross section, reached the top of the Madison limestone at a depth of 9,618 feet which, if this projection is reasonable, is very close to that anticipated by Hume on the basis of his published 1940 cross section. A large flow of gas and distillate was encountered in this hole. A third hole, drilled structurally 1,000 feet downdip only $\frac{3}{4}$ mile from the second

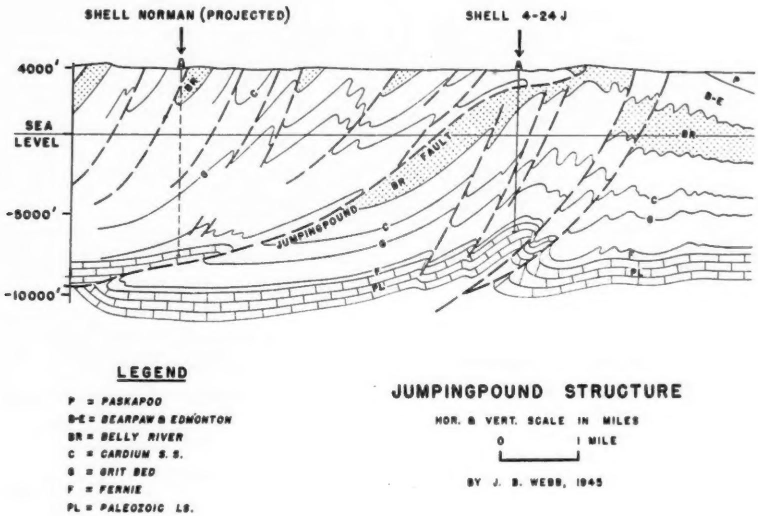


FIG. 9

hole, encountered water; a fourth, slightly up the dip from the third, encountered water, gas, and distillate; and a fifth was completed as a gas producer in the Madison at 9,793 feet, after being drilled to the total depth of 14,443 feet and after passing through a fault and encountering the Madison limestone the second time at 10,735 feet, in which block drilling was continued into the Cambrian.

Figure 9 is a cross section prepared by J. B. Webb, prior to completion of this last well, in which he postulated a branching major fault cutting the Paleozoic limestone. This cross section is indeed very close to the true picture as revealed by the drilling of the last well in which a repetition by one fault was disclosed.

To be noted is Hume's suggestion that the fold postulated by him is probably faulted and more tightly folded, which indeed it was. Different versions of this lower structure could be constructed, but the main point in this figure is an

example of a prospective oil and/or gas field below a thin surface overthrust sheet which appears to be unrelated to the one above, and still another block at greater depth.

BRAZEAU STRUCTURE

Six companies joined in a venture to drill the Brazeau structure, of which an interpretation as prepared by Imperial geologists is presented herewith. This is an inner Foothills fold of great magnitude.

Figure 10 is a cross section through the Brazeau structure where one hole

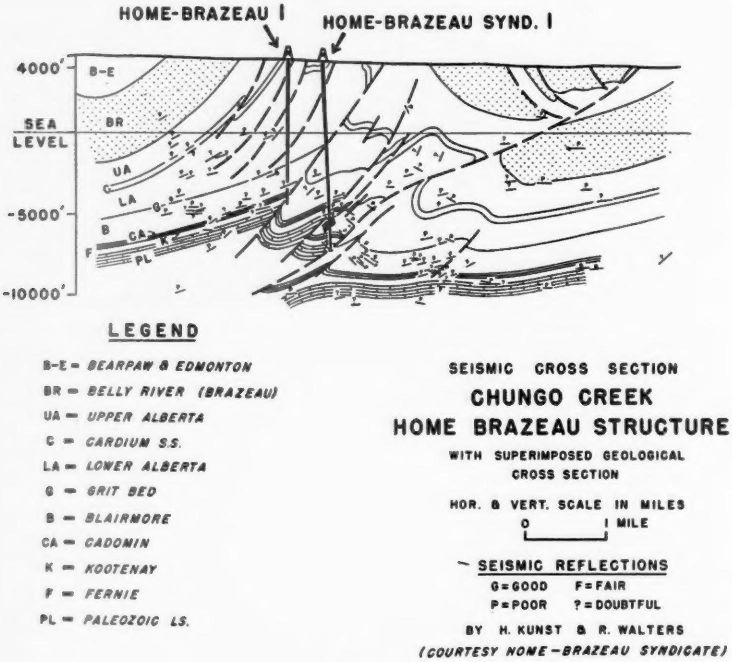


FIG. 10

(Home-Brazeau 1), which had to be abandoned because of mechanical difficulties, failed to reach the objective. The second, or joint venture, reached the top of the Paleozoic limestone at a depth of 9,498 feet, only to encounter another fault, and then enter the limestone for the second time at a depth of 11,351 feet. On this cross section are shown the seismic reflections obtained by running a profile across the structure. This cross section is an attempt to reconcile the seismic data with the surface geology and the logs of the holes drilled.

Figure 11[5] is a cross section along a line slightly north, prepared before the drilling of the wells and without the use of seismic data—in other words, a section based on surface geology only. The Paleozoic limestone was expected at a depth of 4,500 feet, but the drilling of the first and second hole did not confirm this expectation and the top of the limestone was encountered at a depth of 9,498 feet, which was within an error of 50 feet predicted by the seismologists who, however, did not anticipate the faulting encountered below.

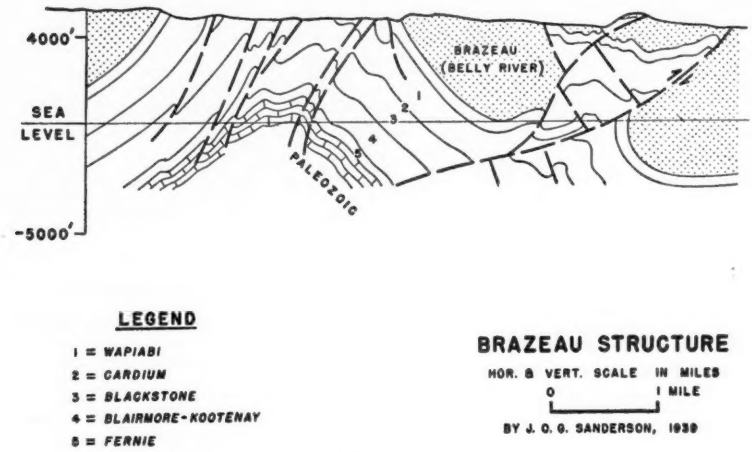


FIG. 11

STOLBERG STRUCTURE

The Stolberg structure (Fig. 12) was drilled jointly by the Shell and Imperial to the total depth of 13,747 feet—at that time the deepest hole in western Canada. On the basis of seismic data, indicated on the cross section, the Paleozoic limestone was expected at a depth of approximately 9,000 feet, but a depth of 12,218 feet was drilled before the limestone was encountered, and from that depth to the bottom of the hole the limestone was repeated by faulting three times (the lowest at the depth of 13,118 feet). There was no faulting of major significance in the formations above the limestone. The misjudgment in depth was the result of miscorrelation of beds in the complicated fault zone where Blairmore reflections were mistaken for limestone reflections. As in previous cross sections, the seismic data, surface geology, and the well logs are reconciled as closely as possible. Obviously, numerous other interpretations could be made, but the general picture would probably be the same. It is superfluous to suggest that no two

[5] J. O. G. Sanderson, "Geology of the Brazeau Area," *Canadian Inst. Min. Met. Eng.*, Vol. 42 (1939), pp. 429–42.

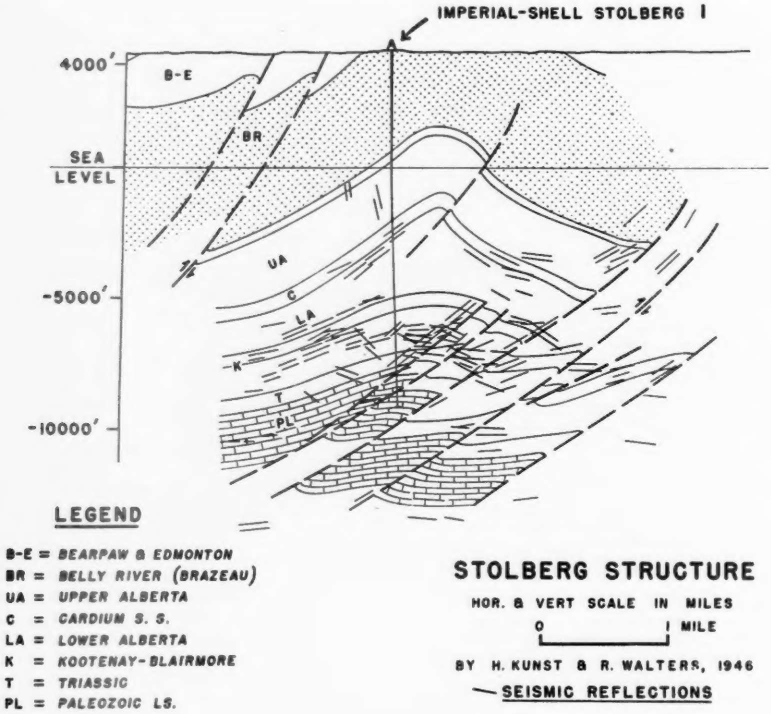


FIG. 12

geologists and/or geophysicists would produce exactly the same picture even though they are supplied with the same data, and even though they had the same training. The Stolberg structure is an outer Foothills fold, and major faulting is absent from the surface down to the top of the Paleozoic limestone.

COALSPUR STRUCTURE

A most interesting structure (as far as giving leeway to the imagination and variety of interpretation) is the Coalspur structure drilled by the Imperial Oil Limited in 1945, where the top of the limestone was encountered at 12,756 feet. One interpretation of it is illustrated in Figure 13. In this part of the Foothills belt some of the outer folds exhibit, at the surface, steeper dips on the west side, as shown in this illustration. Several geologists have suggested an active push from the east to account for this apparent reversal of conditions, well knowing that the entire Rocky Mountain and Foothills orogeny indicates active forces from the west. The deep test and the seismic records seem to indicate clearly that the forces came from the west, and that the underthrusting is surficial.

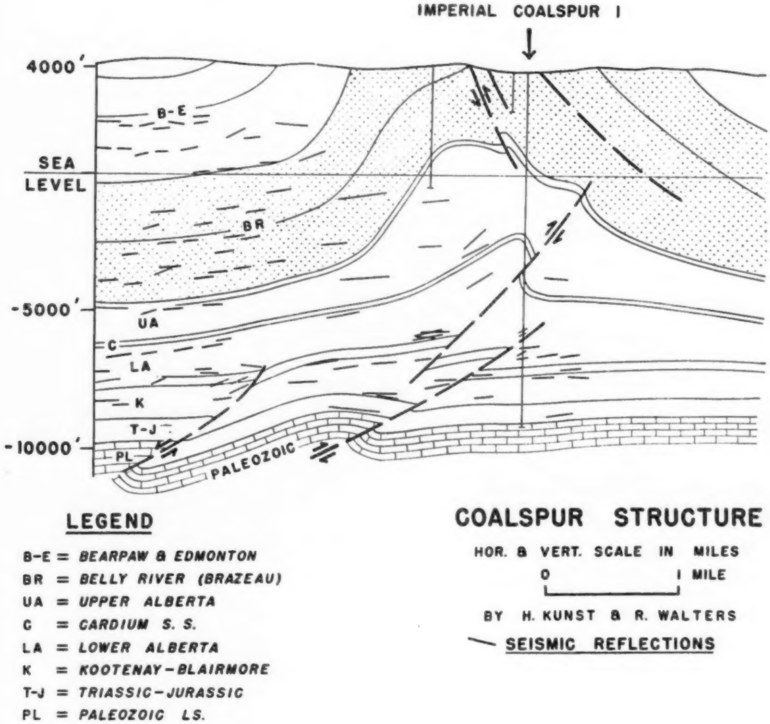


FIG. 13

The interpretation shown here postulates limited near-surface underthrusting and the typical overthrusting at depths, but limited to such an extent that essentially no structure exists. The low seismic dips at depth on the west flank are not used in this interpretation, and in Figure 14 is shown an alternate version indicating more pronounced underthrusting (nevertheless surficial) which uses the low-dip seismic-reflection records encountered at considerable depths on the west flank and the very high dips observed and plotted at the surface.

SAVANNAH CREEK STRUCTURE

The presence of large-scale folded faults and/or folded thrust sheets in the Alberta Foothills has been recognized for some time, and much has been published regarding that subject during the last decade. This contribution could not be regarded as adequate without at least one clean-cut and undeniable example. Figure 15 shows the geological conditions as observed in the area of the north

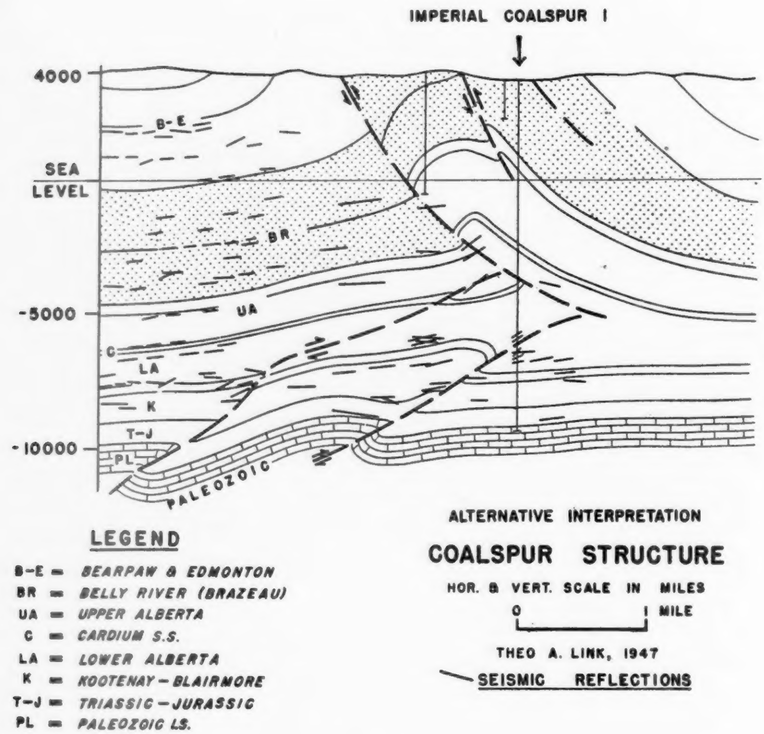
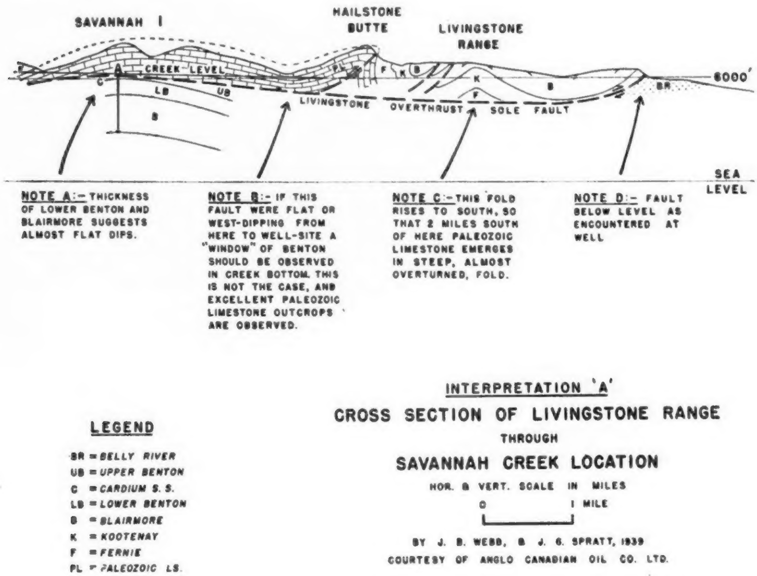


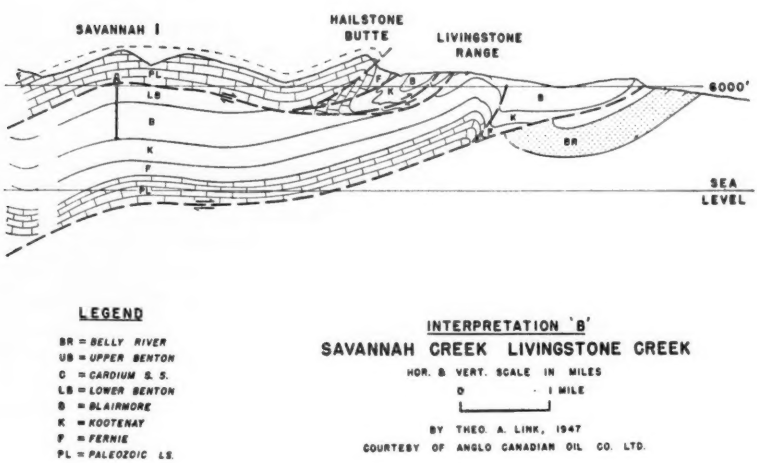
FIG. 14

Livingstone Range, which consists of several Paleozoic limestone folds or outliers lying directly in front of the Rocky Mountains in the southern Alberta Foothills. This cross section was prepared by J. B. Webb on the basis of the surface geology and a well drilled by the Anglo-Canadian Oil Company to a depth of 3,375 feet as indicated on the left or west side of the section. The location was chosen on a large dome-like anticline of Paleozoic limestone. The intention was to test the Devonian and older Paleozoic but, after drilling hardly more than 40 feet, the drill passed through a major sole fault into the Upper Cretaceous "Benton." This fault must lie at a lower elevation downstream along the creek east of the well location. The creek bottom is Paleozoic limestone, as indicated under note B. According to Webb, the fault emerges at the surface farther east after involving above it another fold which, only 2 miles south of the line of section, as indicated under note C, involves another Paleozoic limestone fold. Webb's interpretation is the most conservative possible, and there is no doubt that the sole fault is warped or folded.



SAVANNAH I
HAILSTONE BUTTE
LIVINGSTONE RANGE
CREEK LEVEL
6000'
LIVINGSTONE OVERTHRUST
SOLE FAULT
SEA LEVEL
NOTE A:- THICKNESS OF LOWER BENTON AND BLAIRMORE SUGGESTS ALMOST FLAT DIPS.
NOTE B:- IF THIS FAULT WERE FLAT OR WEST-DIPPING FROM HERE TO WELL-SITE A "WINDOW" OF BENTON SHOULD BE OBSERVED IN CREEK BOTTOM. THIS IS NOT THE CASE, AND EXCELLENT PALEOZOIC LIMESTONE OUTCROPS ARE OBSERVED.
NOTE C:- THIS FOLD RISES TO SOUTH, SO THAT 2 MILES SOUTH OF HERE PALEOZOIC LIMESTONE EMERGES IN STEEP, ALMOST OVERTURNED, FOLD.
NOTE D:- FAULT BELOW LEVEL AS ENCOUNTERED AT WELL
LEGEND
BR = BELLY RIVER
UB = UPPER BENTON
C = CARDIUM S. S.
LB = LOWER BENTON
B = BLAIRMORE
K = KOOTENAY
F = FERNIE
PL = PALEOZOIC LS.
INTERPRETATION 'A'
CROSS SECTION OF LIVINGSTONE RANGE
THROUGH
SAVANNAH CREEK LOCATION
HOR. & VERT. SCALE IN MILES
0 1 MILE
BY J. B. WEBB, & J. G. SPRATT, 1939
COURTESY OF ANGLO CANADIAN OIL CO. LTD.

FIG. 15



SAVANNAH I
HAILSTONE BUTTE
LIVINGSTONE RANGE
6000'
SEA LEVEL
LEGEND
BR = BELLY RIVER
UB = UPPER BENTON
C = CARDIUM S. S.
LB = LOWER BENTON
B = BLAIRMORE
K = KOOTENAY
F = FERNIE
PL = PALEOZOIC LS.
INTERPRETATION 'B'
SAVANNAH CREEK LIVINGSTONE CREEK
HOR. & VERT. SCALE IN MILES
0 1 MILE
BY THEO. A. LINK, 1947
COURTESY OF ANGLO CANADIAN OIL CO. LTD.

FIG. 16

Figure 16 is a slightly different interpretation of the same data wherein the folded fault is postulated as emerging through several branching faults west of the other fold, and the latter is indicated as being underlain by a second, lower-lying, major sole fault emerging on the east. Under this interpretation the first fault is folded more than that suggested by Webb. Figure 17 is another interpre-

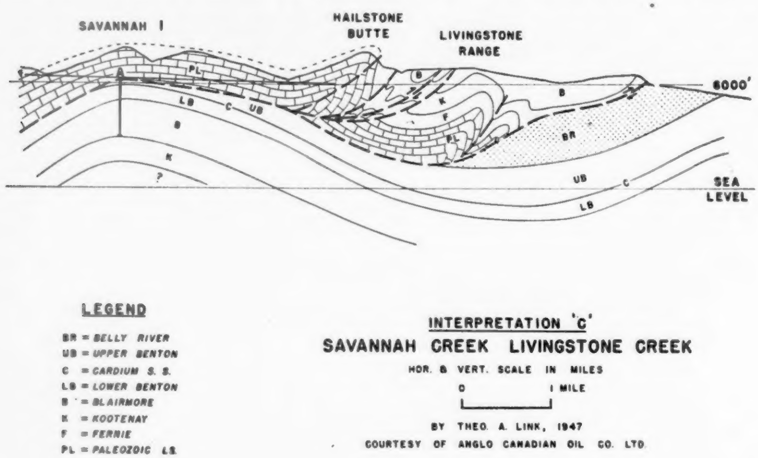


Fig. 17

tation, essentially the same as that of Webb, but with extreme folding of the major thrust fault, and more like some of the folded thrust sheets or nappes as mapped by European geologists in the Alps. A folded fault or thrust sheet in the Foothills so close to the Rocky Mountains is not to be regarded as a novelty, as it is a normal condition to be expected, because this part of the Foothills was deformed during the earlier stages of the orogenic history, and was subjected to additional folding and faulting until the end of the orogenic movements.

MUSKEG STRUCTURE

Five major companies joined to drill the Muskeg structure, which appeared to be an excellent Foothills prospect far at the north. It had been mapped by surface geology, by aerial photography, and by one seismic-reflection profile. A road 75 miles long had to be cut through the rough terrane of the Foothills, and when the project was completed, the cost was approximately 1½ million dollars. This hole was drilled to 10,709 feet, and was abandoned in the Madison (Rundle) limestone which was reached at 9,638 feet. The persistence of the Shell Oil Company in attempting to develop a commercial field in the Jumping Pound area is another example of high-cost exploration in the Foothills, all of which throws more light on these perplexing problems for those who, in the future, may be bold enough to try again.

PINCHER CREEK STRUCTURE

Since delivery of this paper at the Los Angeles meeting of the Association in 1947, an important discovery of wet gas and distillate was made by the Gulf Oil Company in the Foothills area near Pincher Creek, Alberta.

This discovery was the result of an intensive seismic-refraction survey which indicated the probable presence of a Paleozoic limestone block at a depth of approximately 12,000 feet. According to officials of the company, the drill encountered the Madison (Rundle) limestone within 400 feet of the depth predicted by the seismic surveys. Unfortunately, no cross section is available for submittal in this contribution. However, this discovery will undoubtedly be the forerunner of renewed exploration in the Foothills areas of Alberta and British Columbia, and these will add to the oil and gas possibilities of western Canada. As permission to export natural gas from Alberta to other parts of Canada and potential consuming centers in the near-by northwestern United States is being sought, discoveries of this nature may eventually play a very important part in granting this permission and in the ultimate economy of Alberta and western Canada.

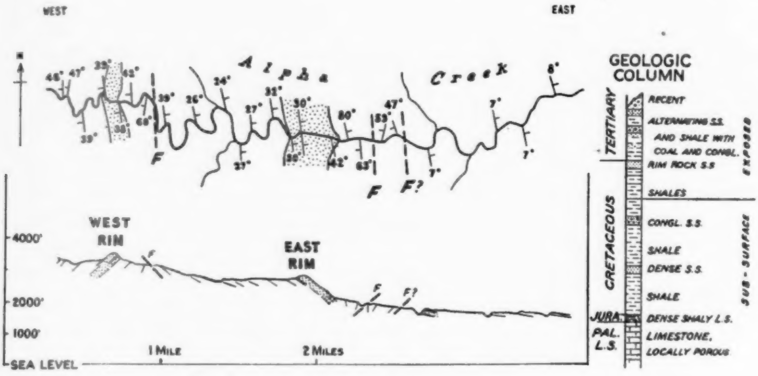
GENERAL REMARKS

It is clear that with the aid of geophysics and deep drilling, considerable progress has been made in the interpretation of Alberta Foothills structures at depth. The data obtained by drilling the Turner Valley structure, additional surface geological mapping, and the drilling of one or several holes on other prospects have all contributed toward a better understanding. These data, implemented with seismic-reflection records, make it possible to predict with a more reasonable certainty what is to be expected beneath the surface. However, as no two Foothills structures are exactly alike, and as no two cross sections of the same structure are identical, correct interpretations or predictions are not now, and probably never will be, possible.

This presentation began with Turner Valley where data are sufficient to present very reasonable interpretations. The other examples presented were taken from other parts of the Alberta Foothills where considerable information is available but where speculation must still be resorted to in spite of excellent surface geological mapping, aerial photographs, and seismic-reflection data. In some places more than one deep drilling test has added more information but it is obvious that reasonably correct final interpretation of a structure can not be obtained until it has been almost completely exploited. Experience in Turner Valley has taught that each new drilling location caused a slight, and in some places a radical, change of interpretation as the field was being drilled. The last part of this contribution consists of an example of the method of attack in the interpretation of Foothills structures on the basis of surface geology and seismic-reflection records.

ALPHA STRUCTURE

In Figure 18 is indicated a typical geological traverse usually available after mapping a representative Foothills structure. The structure profile is plotted



"ALPHA" STRUCTURE

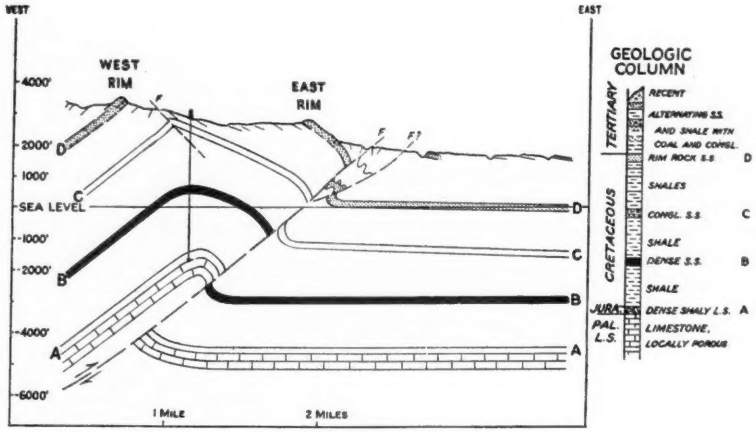
SURFACE GEOLOGY & PROFILE

FIG. 18

below the traverse of Alpha Creek, where reasonably good outcrops were observed and mapped as indicated. Limited to an almost insignificant vertical range, the geologist must construct the cross sections on the basis of which a deep test, costing possibly $\frac{1}{2}$ million dollars, might be drilled. The method of attacking the problem is dependent on the geologist's experience and previous training. As a result, no two geologists will submit identical interpretations, and in many cases widely divergent interpretations are submitted based on the same field data.

Figure 19 (interpretation A) is a conservative, or orthodox, cross section which interprets the fault within the rim rock to be a minor underthrust fault, and the zone of faulting east of the rim rock as a zone of major overthrust faulting. A slight amount of thickening of sediments is postulated at the crest of the structure, thus placing the prospective producing zone below bed A at a depth of approximately 4,400 feet at the drilling site indicated. In constructing this cross section the geologist also had available the measured geologic section and the stratigraphic sequence indicated in the geologic column on the east. The unexposed part of this geologic column was presumably measured west of the map and cross-section area.

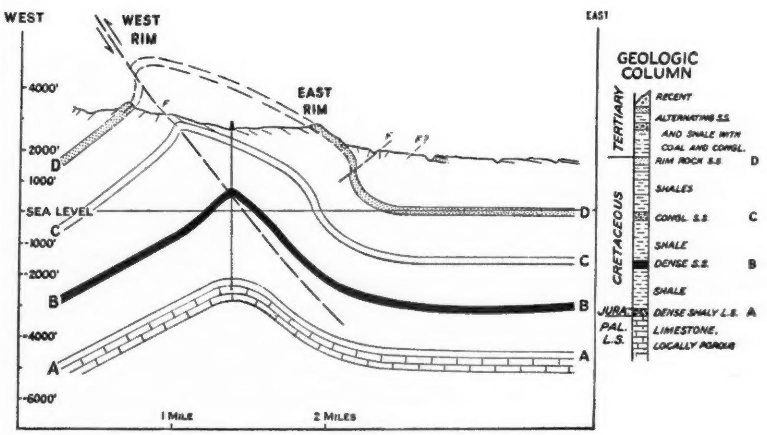
Figure 20 (interpretation B) is a cross section in which the geologist interprets the faulting observed east of the rim rock as of minor significance, but regards the fault observed within the rim rock, as well as the steeper west-flank dips, as



"ALPHA" STRUCTURE

INTERPRETATION A

FIG. 19

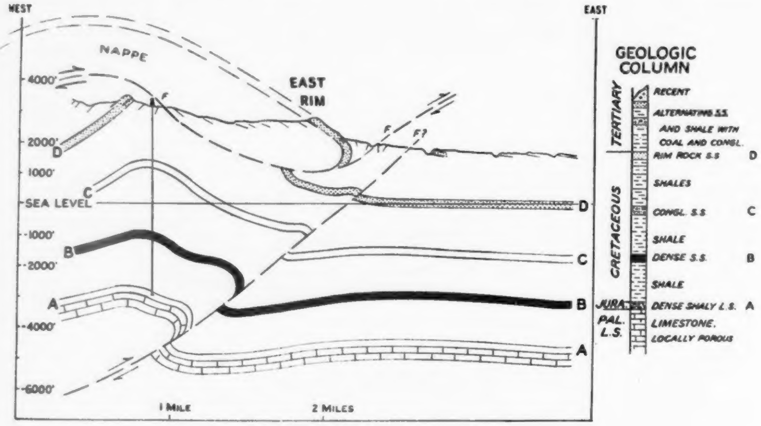


"ALPHA" STRUCTURE

INTERPRETATION B

FIG. 20

indicating an overthrust from the east of major significance. However, the crest of the structure at depth is placed approximately in the same position as in interpretation A, with a depth of 5,000 feet indicated for the prospective producing zone. The Coalspur structure, previously referred to, presents similar surface data and was regarded by some geologists as evidence of major overthrusting from the east. Closer examination of this interpretation reveals that the geologist was experiencing difficulty with respect to the displacement of the supposed major east-dipping overthrust fault at depth. The fault could have been steepened considerably so as to involve the prospective oil zone on the upthrown side.



"ALPHA" STRUCTURE

INTERPRETATION C

FIG. 21

Figure 21 (interpretation C) is a cross section based on the same data, but constructed by a geologist who learned his structural geology in the Alps, or by one who was influenced by studying the interpretations suggested by students of Alpine geology, whose nappes, klippen, and folded thrust sheets are favorite features usually included in structural cross sections. The fault inside the rim rock is regarded as a folded overthrust which emerges east of the rim rock in the area where faulting and crumpling were also observed. The eastern limit of the fault zone east of the rim rock is interpreted as a conventional overthrust from the west, placing the prospective producing zone at a depth of approximately 6,000 feet at a location chosen slightly west of those of interpretations A and B. Thickening of the beds near the crest of the structure is again judicially postulated. Hake, Willis, and Addison[6] interpreted the Brazeau structure previously

[6] B. F. Hake, Robin Willis, and C. C. Addison, "Folded Thrust Faults in the Foothills of Alberta," *Bull. Geol. Soc. America*, Vol. 53 (February, 1942).

described as being composed of at least six folded overthrust sheets. Folded faults and thrust sheets are present in the Alberta Foothills, as illustrated in the Savannah Creek area (Figs. 15, 16, and 17), but their use should not be overdone.

The preceding three interpretations do not exhaust the possibilities. It is obvious that a geophysical survey is now in order. Figure 22 shows the reflections obtained from a seismic-reflection profile across the structure. This is an excellent set of reflection records rarely obtained. The reflections are graded good, fair, and questionable, and with these data it is obvious that the geologists and the geophysicists must cooperate. It looks much like a hopeless task, but with knowledge of the stratigraphic section and sequence, and of previously drilled Foothills

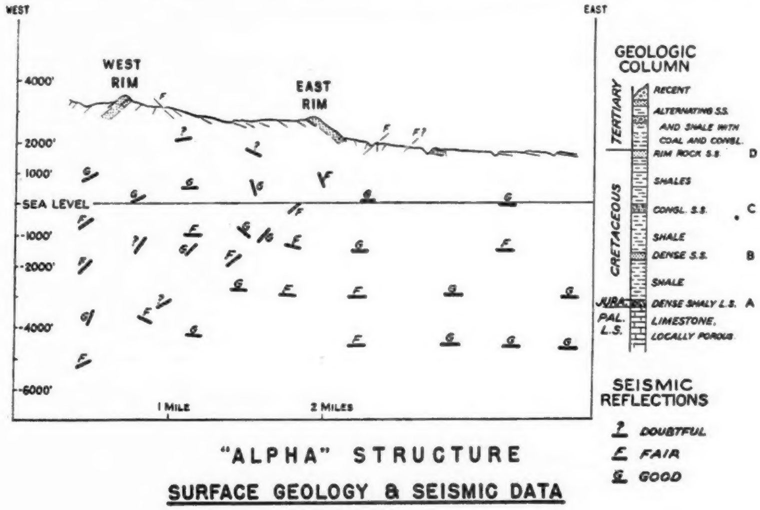
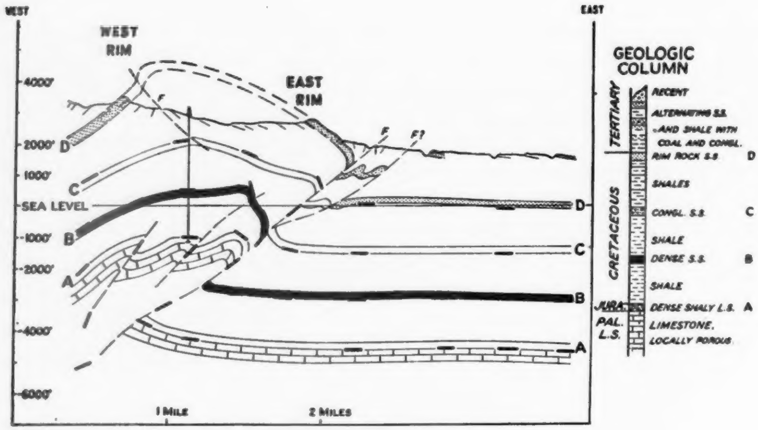


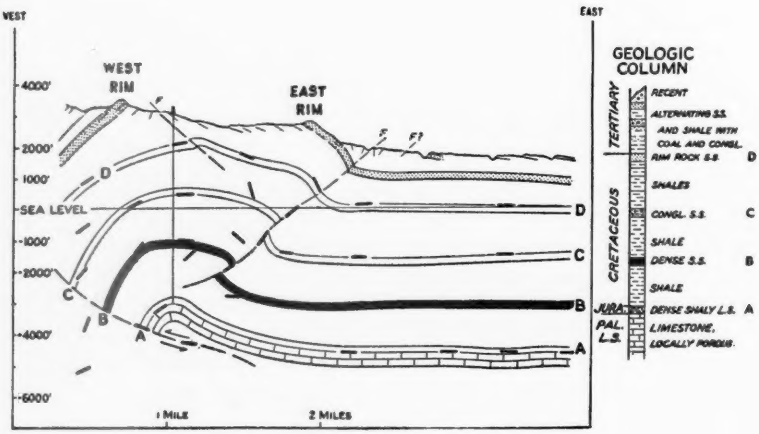
FIG. 22

structures, reasonable interpretations should be forthcoming. It appears definite that the west-dipping thrust fault or fault zone is present, as indicated by five west-dipping reflections, directly west of the gentle dips extending from the Basin, from which the survey was run westward toward the Foothills. Figure 23 (interpretation D) is regarded by the geologist and the geophysicist as a reasonable interpretation. The thrust fault inside the rim rock is interpreted as a minor underthrust adjustment fault. Two other thrust faults are postulated west of the major sole fault at depth, and considerable thickening and thinning of beds are indicated. The prospective producing zone is expected at a depth of 4,000 feet at a location chosen close to the selections made under the other interpretations. Obviously, other interpretations of similar nature could be made, but a radically different one is submitted as Figure 24 (interpretation E), wherein the geologist favors the theory of overthrusting from the east. In this section the



"ALPHA" STRUCTURE
INTERPRETATION D

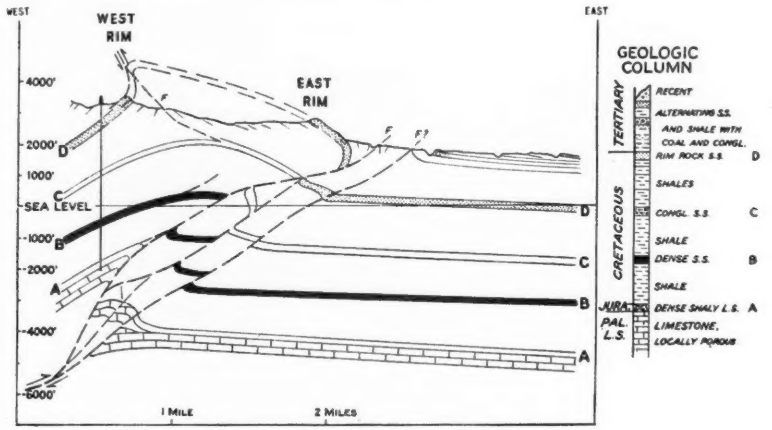
FIG. 23



"ALPHA" STRUCTURE
INTERPRETATION E

FIG. 24

west-dipping reflections and the observed outcrop of the thrust faults east of the east rim rock are interpreted as a minor adjustment underthrust, and the steeper dip of the west rim rock is emphasized so that the postulated east-dipping sole fault is suggested as emerging somewhere west of this cross section. Trouble is encountered in the geologic section in dealing with the bed forming the rim rock. The prospective producing zone is postulated at a depth of 6,000 feet at a location close to those chosen in the previous interpretations. It is to be noted that several seismic-reflection records were disregarded or ignored, as was usually the case in many of the cross sections previously shown. This is very common practice, but it generally leads to misinterpretations.



"ALPHA" STRUCTURE

FINAL INTERPRETATION

FIG. 25

The question is now "What is the correct interpretation of the surface geologic and seismic-reflection data available for the Alpha structure?" Figure 25 is a cross section of this structure correct in practically every detail. The branching major overthrust fault or fault zone is very much like the north end of Turner Valley, and also similar to the Brazeau structure previously described. Observe the east-dipping fault blocks below the main fault, and the gradual decrease in displacement of the overthrust faults toward the surface, and the decrease in displacement at depth of the underthrust fault inside the rim rock which terminates as a bedding-plane fault on bed C. Note also the upward bend of the top overthrust fault and the thickening of beds near the crest of the faulted anticlinal fold. To reach the prospective producing zone on this structure above the major sole fault it is necessary to locate the well west or outside of the rim rock, and

the depth will be found at approximately 5,200 feet as indicated. In other words, all previous interpretations and well-location recommendations would have been failures, as the limestone would have been encountered on the downthrown side of the thrust sheet.

The logical question for the reader to ask now is: "How does the writer know that this is the correct interpretation?" The answer is, the writer made the structure in the laboratory, and Figure 26 is a picture of a section cut through it. Space will not permit pointing out where the mistakes in interpretation were made and the reader can do that for himself. It suffices to say that miscorrelation of beds above and below the major sole faults is a primary cause of misinterpretation of seismic data in the Foothills. Also, seismic velocities commonly change in passing from the relatively undisturbed Basin area into the foothills, and this is one of

FIG. 26.—Cross section of Alpha structure as made in laboratory, and of which Figure 25 is a drawing. ("Tertiary" of Figure 25 was overburden in this experiment, and removed before cutting the section.)

the several causes of miscalculation. Difficulty in differentiating between reflections from fault planes and bedding planes is another, and rough terrane with resultant large variations of surface elevations also contributes to the confusion. The geophysicists can probably enumerate many other technical reasons. Nevertheless, it must be admitted that the first interpretation based on the combination of the surface geological and seismic-reflection data (interpretation D) was indeed very reasonable and probably much closer than is usually the case in actual practice. However, on several occasions in the Alberta Foothills the prospective Paleozoic limestone has been reached at depths very close to those predicted by the seismic surveys. The Brazeau structure is an example. Unfortunately in this case the repetition of the prospective Paleozoic limestone was not predicted and only the drilling of the deep test proved such repetitions.

FOLDED FAULTS

In Figures 25 and 26 the upper overthrust fault can be clearly traced from depth (at the left) eastward toward the surface, and it is slightly arched with concave side down. The thrust fault directly beneath is also slightly arched, but the last or lower-overthrust fault is essentially straight at an angle of 45°. The manner in which this may take place is illustrated in Figure 27. In the progressive development of this structure, stage I shows the first overthrust fault, developed at an angle of approximately 45°, and fairly straight. In stage II, a second overthrust fault has developed, again at an angle of approximately 45°, but the first one shows signs of up-bowing or warping. This is because the underthrust fault, developed near the surface, caused the mass to rise higher on the west side. The first overthrust fault was bent upward correspondingly. The amount of rise is indicated by the arrows near the surface. In stage III, a third overthrust fault has

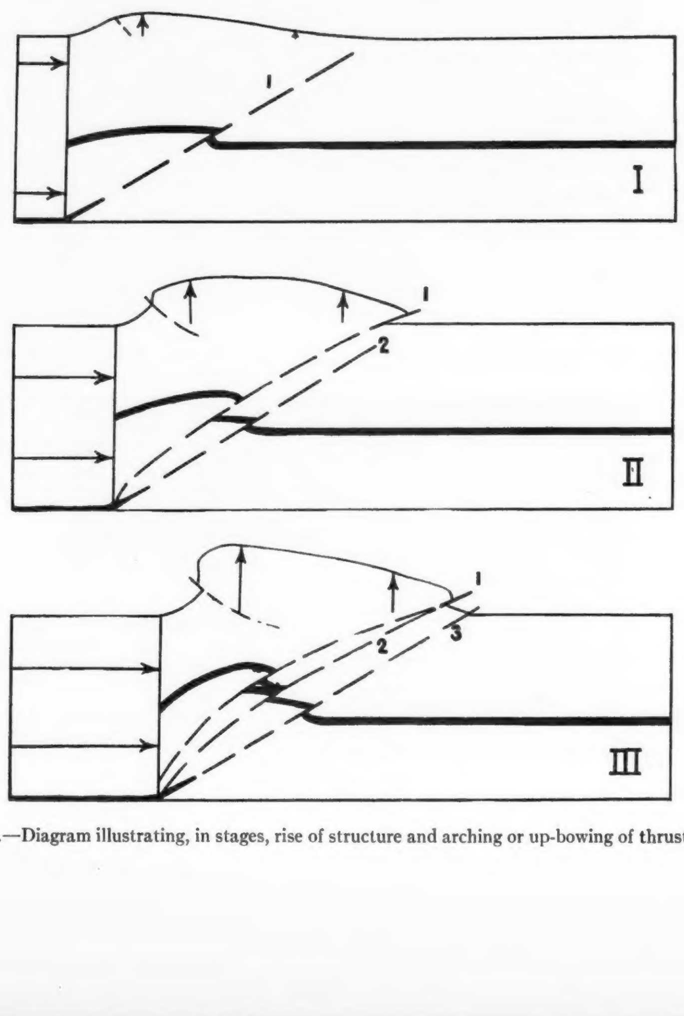


FIG. 27.—Diagram illustrating, in stages, rise of structure and arching or up-bowing of thrust faults.

developed, again in a straight line, more or less at an angle of 45°, and the two previously developed overthrust faults have been further arched or bowed upward because of the continued rise of the mass on the west side. Thus, it is apparent that folding or bending of overthrust sheets is entirely possible and highly probable.

Another cross section through the same structure is indicated in Figure 28 but in this case practically all of the uplift of the mass was on the east side where the overthrust fault emerged at the surface. Here the three major thrust faults were not arched or bent upward, but continued in their original, generally straight-line direction, at an angle of slightly less than 45°. This seems to indicate that during the same orogenic movement overthrust fault planes might and might

Fig. 28.—Another cross section of Alpha structure, showing no warping or up-bending of faults.

Fig. 29.—Another cross section of Alpha structure similar to Figure 26, showing some warping of first thrust fault, and an incipient thrust fault which did not reach surface.

not be warped, depending on local conditions in the same structure. Figure 29 is another cross section through the same structure which is more or less intermediate between the two illustrated in Figures 26 and 27.[7]

CONCLUSIONS

Following is a summary of the main features which the writer has attempted to convey.

1. The structural geology of the Foothills of western Canada is complicated, and far from being completely understood. Aided by recent deep drilling and the application of geophysical methods, some progress has been made toward solving the problem of choosing well sites for testing the prospective producing zones of the Paleozoic.

2. Underthrusting or apparent overthrusting from the east is a near-surface phenomenon, in some instances initiated during the incipient stages of the development of folds, or as an adjustment feature only, but never a primary or major phenomenon.

3. Warping, up-bowing, and folding of overthrust faults and sheets are recognized features of Foothills structure, less common near the eastern edge, but becoming more pronounced westward toward the Rocky Mountains.

4. Because of variations of stress intensity, direction and mode of operations, and change of sedimentary sections and other factors, no two Foothills structures are alike. This also applies to cross sections on the same structure, as illustrated in Turner Valley and in the laboratory.

[7] For a complete set of cross sections through this model see Figures 12–17, *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15, No. 4 (April, 1931), p. 395.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 33, NO. 9 (SEPTEMBER, 1949), PP. 1502-1552, 4 PLATES, 10 FIGS.

DEVONIAN AND MISSISSIPPIAN STRATIGRAPHY, WAPITI LAKE AREA, BRITISH COLUMBIA, CANADA[1]

L. R. LAUDON,[2] ELGIN DEIDRICK, EDWIN GREY, WARREN B. HAMILTON, PAUL J. LEWIS, WILLIAM McBEE, A. C. SPRENG, AND ROGER STONEBURNER
Madison, Wisconsin

ABSTRACT

Wapiti Lake lies in the folded, thrust-faulted eastern edge of the Paleozoic rocks in British Columbia, approximately 90 miles southeast of the Peace River. Transportation of men, supplies, and equipment into the area was by amphibian plane.

Cambrian, Devonian, Mississippian, and Triassic rocks were identified. Only Devonian and Mississippian rocks were studied in detail.

Devonian rocks consist of: the Fairholme shale, 350 feet thick (base not exposed); the Palliser limestone, 1,005 feet thick; and the Exshaw shale, 57 feet thick. Coral-reef limestones suggesting possible oil-reservoir rocks are well developed in the central part of the Palliser formation.

Three formations of Mississippian age were recognized. The Banff formation, 690 feet thick, Kinderhook in age, and a correlative of the Lodgepole of Montana, contains black shale at the base followed by remarkably cyclic, nodular, shaly, very fossiliferous limestone. The Banff formation is followed by 1,170 feet of cyclic, massive, gray limestone beds that alternate with zones of black shaly limestone. These beds contain the "Z" zone fauna of Europe and are correlated with the lower part of the Mission Canyon formation of Montana. A new formation name, Dessa Dawn, is proposed for them. The Rundle formation (restricted) 510 feet thick, consists of cyclic, soft, brown, porous dolomite that alternates with gray, hard dolomite and rests with marked unconformity on the underlying beds. The abundant coral fauna of the Rundle (restricted) is Meramec in age. The soft, brown, porous dolomites near the base of the Rundle offer exceptionally excellent possibilities as oil-reservoir rocks.

Triassic rocks containing well preserved fossil ganoid fishes rest unconformably on the Rundle.

INTRODUCTION

Geologic research in the Wapiti Lake area of British Columbia was made possible through the research funds of two universities. Field work during the summer of 1947 was financed by funds from the graduate school of the University of Kansas. Laboratory studies, technical equipment, and research assistance were made available by aid from the funds of the Wisconsin Alumni Research Foundation.

The large area of the Canadian Rockies between the known Jasper Park region on the south and the Alaska Highway on the north was virtually unknown

[1] Manuscript received, February 28, 1949.

[2] Department of geology, University of Wisconsin.

The writers wish particularly to express sincere appreciation for the support given by Dean John M. Nelson, Dean Ellis B. Stouffer, Dean Paul B. Lawson, and Raymond Nichols of the University of Kansas without whose sincere support this research could not have been undertaken.

We are also indebted to G. S. Hume of the Canadian Geological Survey who made his own set of aerial photographs available in order to expedite the work.

Thanks are extended to the administrative committee of the Wisconsin Alumni Research Foundation for support for the laboratory work and research assistance connected with the preparation of this manuscript.

Particular appreciation is expressed to Charles E. Peterson of Kansas City, Missouri, who acted as pilot for the expedition.

Thanks are also extended to many friends in Grande Prairie, Alberta; to the Royal Canadian Mounted Police; and to the Royal Canadian Air Force. Special thanks are extended to W. J. Rigby of Grande Prairie, Alberta, for services performed throughout the summer in connection with the Saskatoon Lake base camp.

except from rapid reconnaissance geology. Since the Canadian Northwest remains as one of the last potentially promising petroleum areas in North America, the needs for basic research in stratigraphy and paleontology are obvious. Wapiti Lake was chosen as a base for operations because it is well within the unstudied area and because it afforded sufficient runway to accommodate the amphibian plane that was used for transportation into the area. In addition, preliminary reconnaissance by air showed exceptionally well developed Paleozoic sections available in the area.

A seaplane base was constructed on Saskatoon Lake near Grande Prairie, Alberta and the geologic party, equipment, and supplies were flown in to the Wapiti Lake base camp early in June. Weather conditions in the Wapiti Lake area made flying exceedingly difficult during June and the early part of July. Storms in almost continuous succession move eastward from the high ice-covered peaks of the ranges on the west, gradually decreasing in intensity across the Wapiti Lake area as they approach the prairie area. The ground-work was made difficult by one 6-day rain, one 5-day rain, and only 2 days during the entire summer without mid-day storms. Working conditions were much better during the last half of July and the early part of August. The Wapiti Lake base camp was first established at the mouth of Irene Creek on the south shore of Wapiti Lake. This camp was found undesirable because of the heavy bush cover on the lower slopes of the mountains so the base camp was moved to the shores of Camp Lake just downstream from the junction of South Gap Canyon with Wapiti River. The gravels on the floors of North and South Gap canyons afforded easy routes of travel into the mountain areas. Work in the area other than in the immediate vicinity of the base camp was accomplished by pack trips into the areas concerned. During the latter part of the field season one major pack trip was undertaken west into the areas where older rocks were exposed across the continental divide.

LOCATION OF AREA

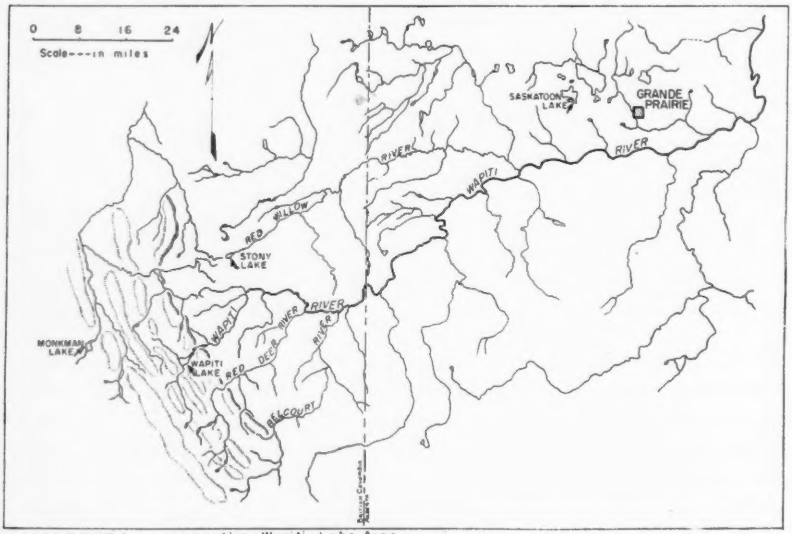
Wapiti Lake is located approximately 100 miles by air S. 51° W. of Grande Prairie, Alberta (54° 36′ N. Lat., 120° 45′ W. Long.). It is a glacial lake near the headwaters of Wapiti River, one of the main tributaries of the Smoky River and lies approximately 14 air miles S. 80° E. of Monkman Lake. Geologically it is located approximately 3 miles southwest of the imposing thrust front of Paleozoic rocks in the Canadian Rockies of this area.

PREVIOUS WORK

No publications concerning geology in the vicinity of Wapiti Lake were available. Geologic information concerning the area between Jasper Park on the south and the Alaska Highway on the north is only of reconnaissance nature.

Since intensive research is now being carried on by a large number of geologists concerning the classification and correlation of Devonian and Mississippian rocks in the Canadian Rockies, it is the writers' policy to be conservative in the

use of new names. In only one case have they found it necessary to introduce a new formation name (Dessa Dawn) and in this case no suitable alternative could be found. The name Dessa Dawn is believed to be a definite, well recognized unit in all of the sections of the southern Canadian Rockies. The name Fairholme (Beach, 1943, pp. 15–17) is used with full recognition of the fact that the Fairholme formation as originally described needs subdivision and that it may eventually be dropped. The rocks in the Wapiti Lake area to which the name Fairholme has been applied may be partly equivalent in time to the rocks of the type section or they may be entirely different. In order not further to complicate



TEXT FIGURE I Location Wapiti Lake Area

the problem of revision of Devonian rocks in this area that is now being undertaken, the older, more inclusive term Fairholme is used.

Since the black, shaly, dolomitic limestone beds containing the *Spirifer jasperensis* fauna are not exposed in the Wapiti Lake area, it is found convenient to recognize three natural units in the Devonian part of the section. The name Fairholme formation (Beach, 1943, pp. 15–17) is used to designate the green, gray shales at the lower part of the section, the name Palliser is used to designate the massive, gray, cliff-forming, coralline limestones that contain the *Cyrtospirifer whitneyi* fauna, and the name Exshaw (Warren, 1937, p. 456) is used to designate the black shales locally developed at the top of the Devonian section. The term Minnewanka limestone (Shimer, 1926, p. 6) is discarded because in its original sense it included all rocks of Devonian age.

The term Banff is retained for the shaly limestone beds at the base of the

Mississippian section although the name Banff in its original sense included beds of Devonian age. Common usage of the name has clarified its meaning so that there is little confusion to-day. The name Rundle is restricted to the gray massive upper limestones that contain a Meramec fauna and the new name Dessa Dawn is proposed for the massive limestones of Kinderhook age above the Banff formation that have heretofore been included in the base of the Rundle formation (Laudon, 1948, pp. 296–297).

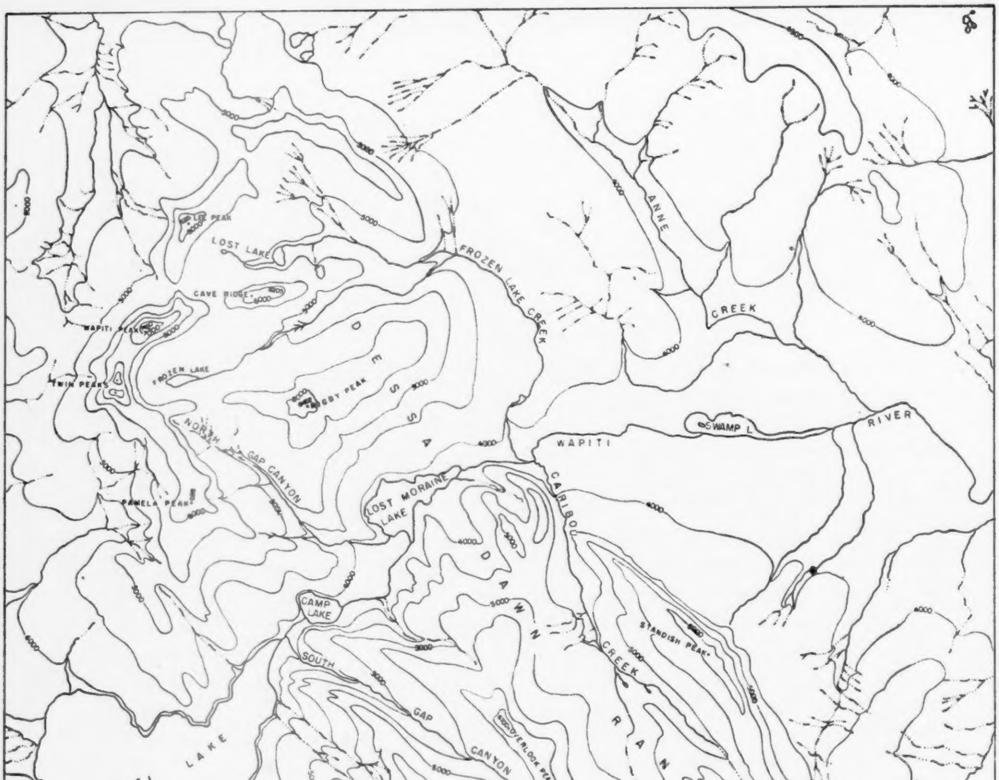
GEOGRAPHIC FEATURES

Essentially all of the local geographic features in the vicinity of Wapiti Lake are without geographic names. The names used in connection with this paper (Fig. 2) serve only to clarify the text and in no way are to be considered as permanent names for the geographic features of the area.

PHYSIOGRAPHY

Paleozoic limestones have been overthrust northeastward onto softer Cretaceous formations in the Wapiti Lake area. Wapiti Lake is approximately 3 miles southwest of the overthrust front. The Paleozoic limestones form an imposing front and have eroded to form high, barren, rugged topography much modified by Pleistocene glaciation. The Wapiti River drainage system has been developed along a fault plane that cuts directly across the regional structures of the area. Wapiti Lake is glacial in origin and was mainly eroded from soft Triassic shales that occupy an extensive syncline in the area where the main body of the lake was formed. The northeast part of the lake extended as far down the Wapiti River valley as Lost Moraine Lake at the end of the Pleistocene. Gravels from North Gap Canyon filled in one part of the lake and gravels from South Gap Canyon filled in another, isolating Camp Lake between the two gravel bodies. The level of Wapiti Lake has been raised about 8 feet by a dam formed by the gravels from South Gap Canyon. Pleistocene ice extended to within 300 feet of the top of Overlook Peak as shown by polished ice surfaces along the walls of the mountain on either side of Wapiti River.

The Palliser limestone of Devonian age is resistant to erosion and, particularly south of Wapiti River, erodes to form a series of high, rugged peaks. Overlook, Patricia, Renie, Standish, and Static peaks are capped with Palliser limestone. The Banff formation is soft and non-resistant to erosion. Deep valleys have been excavated in the Banff formation and the divides along the strike of the Banff formation are low. The low passes designated as Bear Gap, Goat Gap, South Gap, North Gap, and the gap between Wapiti and Twin Peaks have been developed in the Banff formation. The Dessa Dawn and Rundle formations are resistant to erosion and form high, barren, rugged topography. Lee, Wapiti, Twin, Rigby, Dessa Dawn, Meyers, and Melone peaks are capped with Mississippian limestone beds. Triassic rocks are soft and consequently form subdued topography. In general they have been excavated to form the main valleys of the area. The long



TEXT FIGURE 2. Topography and Geographic Features

PL. 1.—Looking northeast across Wapiti Lake.

PL. 2.—Looking southeast, Goat Gap and Meyers Peak in foreground.

Pl. 3.—Structure, southeast wall, South Gap Canyon.

PL. 4.—Structure, looking southeast, Renie Peak in foreground.

valley occupied by Irene Creek and a valley in a similar position north of Wapiti Lake is developed in Triassic rocks.

FIELD METHODS

Since no base map existed with a scale of sufficient magnitude to permit detailed work, a fully corrected base map was constructed from aerial photographs. Topographic control is of reconnaissance type based entirely on uncorrected altimeter readings. Repeated flights from Grande Prairie to Wapiti Lake established the elevation of that lake at approximately 3,995 feet above sea-level. Altimeter readings were made on the more important topographic features in the area but in most cases were made only once and were not corrected for changes in barometric pressure. The topography sketched in Figure 2 can be considered as only slightly better than form lines.

GENERAL STRATIGRAPHIC INTRODUCTION

The Canadian Rockies consist of a series of tightly folded fault blocks that have been overthrust toward the northeast onto Cretaceous rocks in the vicinity of Wapiti Lake. Resistant Paleozoic limestones predominate in the easternmost blocks but older rocks are involved in the structures at the surface in the vicinity of Wapiti Pass on the west.

Rocks of Cambrian and possibly pre-Cambrian age were observed in the vicinity of Wapiti Pass southwest of Wapiti Lake. Since no detailed work was undertaken in this area, no attempt is made to describe the rocks.

Rocks of Devonian age probably rest on the Cambrian rocks although no contact was exposed. No rocks of Ordovician or Silurian age were found and the basal contact of the Fairholme formation was not exposed. It is possible that rocks of Devonian age older than the Fairholme formation may be exposed somewhere in the region although none was observed in the area studied.

The Devonian system is represented by three formations: the Fairholme at the base, followed by the massive limestones of the Palliser, and capped locally with the black shales of the Exshaw formation.

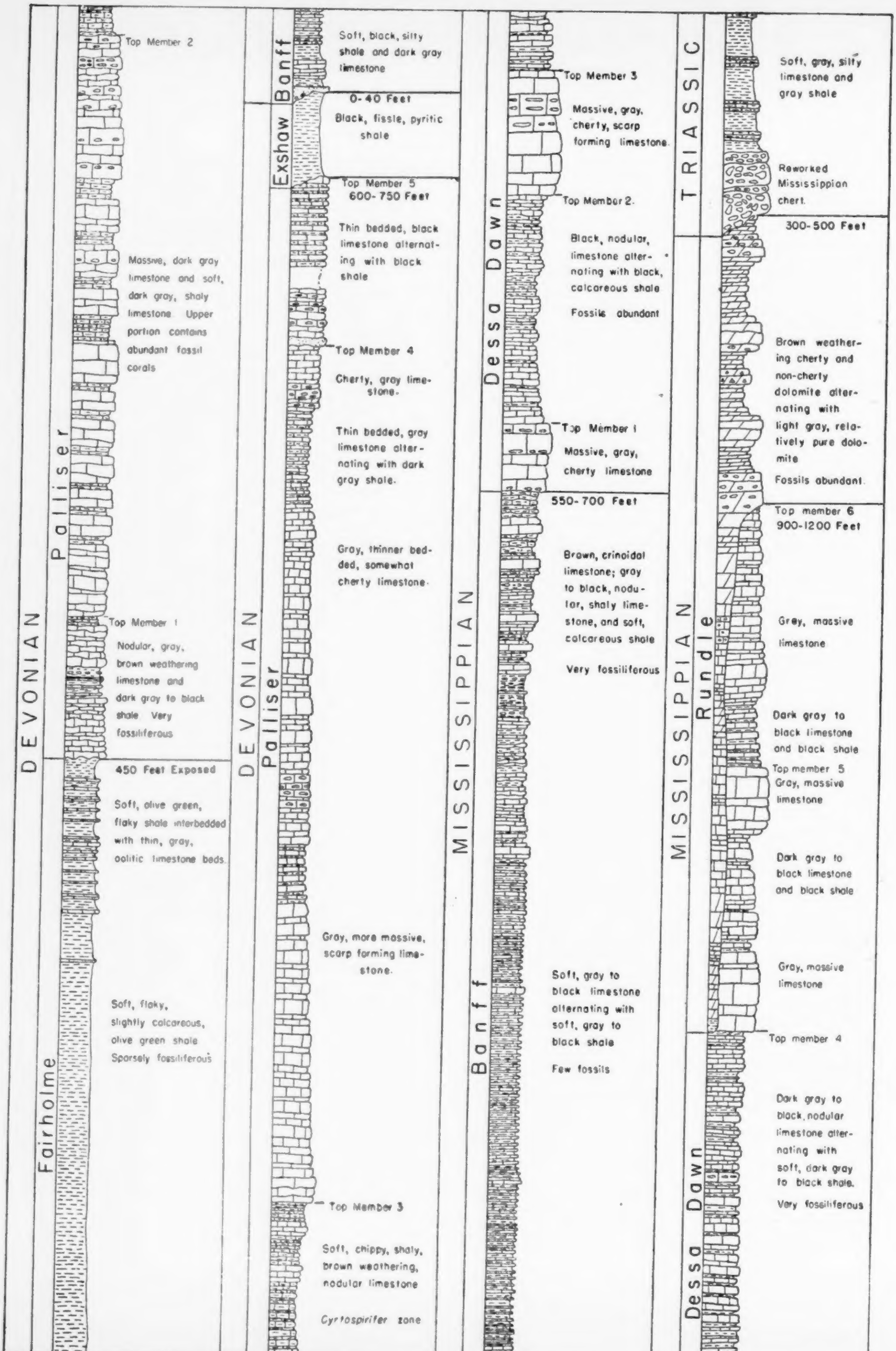
The Mississippian system is represented by three formations: the Banff at the base, followed by the Dessa Dawn (new formation) and capped by the Rundle formation.

No rocks of Pennsylvanian or Permian age were found in the area. Triassic shales and siltstones containing ammonites and numerous ganoid fishes rest directly on the eroded Mississippian surface.

DEVONIAN ROCKS

FAIRHOLME FORMATION

The oldest Devonian rocks exposed in the Wapiti Lake area are referred to the Fairholme formation (Beach, 1943, p. 15). The black, shaly, dolomitic limestones containing the *Spirifer jasperensis* fauna that normally lie at the base of



TEXT FIGURE 3 Formations Exposed in area

the Fairholme formation in southern British Columbia may be present, but were not exposed in the area of study. The Fairholme formation in the Wapiti Lake area consists of 350 feet of soft, thinly laminated, slightly calcareous, waxy, olive-green, clay shale that contains thin, lensing, blue-gray, oölitic limestone beds in the upper part. The oölitic limestone beds range from less than $\frac{1}{4}$ inch to as much as 12 inches in thickness and are interbedded with green shales that range in thickness from as little as 6 inches to as much as 25 feet.

The total thickness and the character of the lower beds of the Fairholme formation were not determined in the area because the base was not exposed. The area is intensely thrust-faulted and the soft shales of the Fairholme formation most commonly formed the gliding plane over which the blocks moved. Due to drag folding and repetition of beds, particularly within the lower part of the Fairholme, it was virtually impossible to obtain an accurate thickness even on the exposed parts of the formation.

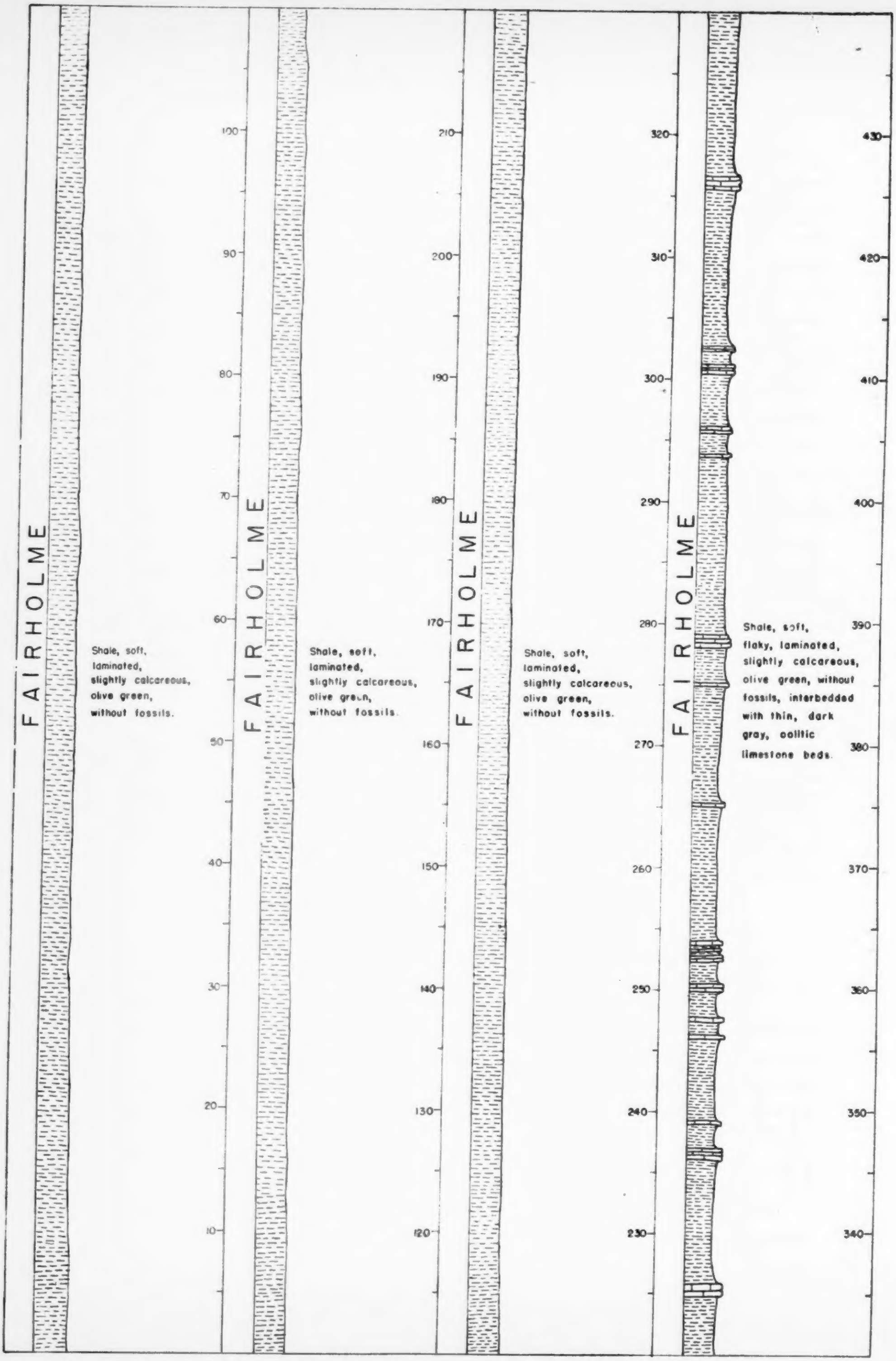
Paleontologic evidence is insufficient to attempt correlation since fossils are exceedingly rare in the Fairholme formation. The only species that occurs in any abundance is *Atrypa* aff. *A. devoniana*. The form is smaller and apparently ancestral to *A. devoniana*.

Stratigraphic position and lithology of the Fairholme, however, allow close correlation throughout the Canadian Rockies. Shales with color and lithology similar to the Fairholme occur beneath the sheer Palliser scarp in the Palisade section in Jasper Park. Similar shales but markedly more fossiliferous lie at the base of the Palliser scarp in the exposures along North Saskatchewan River in the vicinity of the North Saskatchewan River camp ground on the Columbia Ice Fields highway. They form a pronounced bench along the mountain front from the Saskatchewan River crossing to Sunwapta Pass. Shales of similar nature occur at equivalent stratigraphic positions in the Lake Minnewanka area in Banff Park and near Crowsnest Pass in southern Alberta. In the Crowsnest area the shales are markedly fossiliferous.

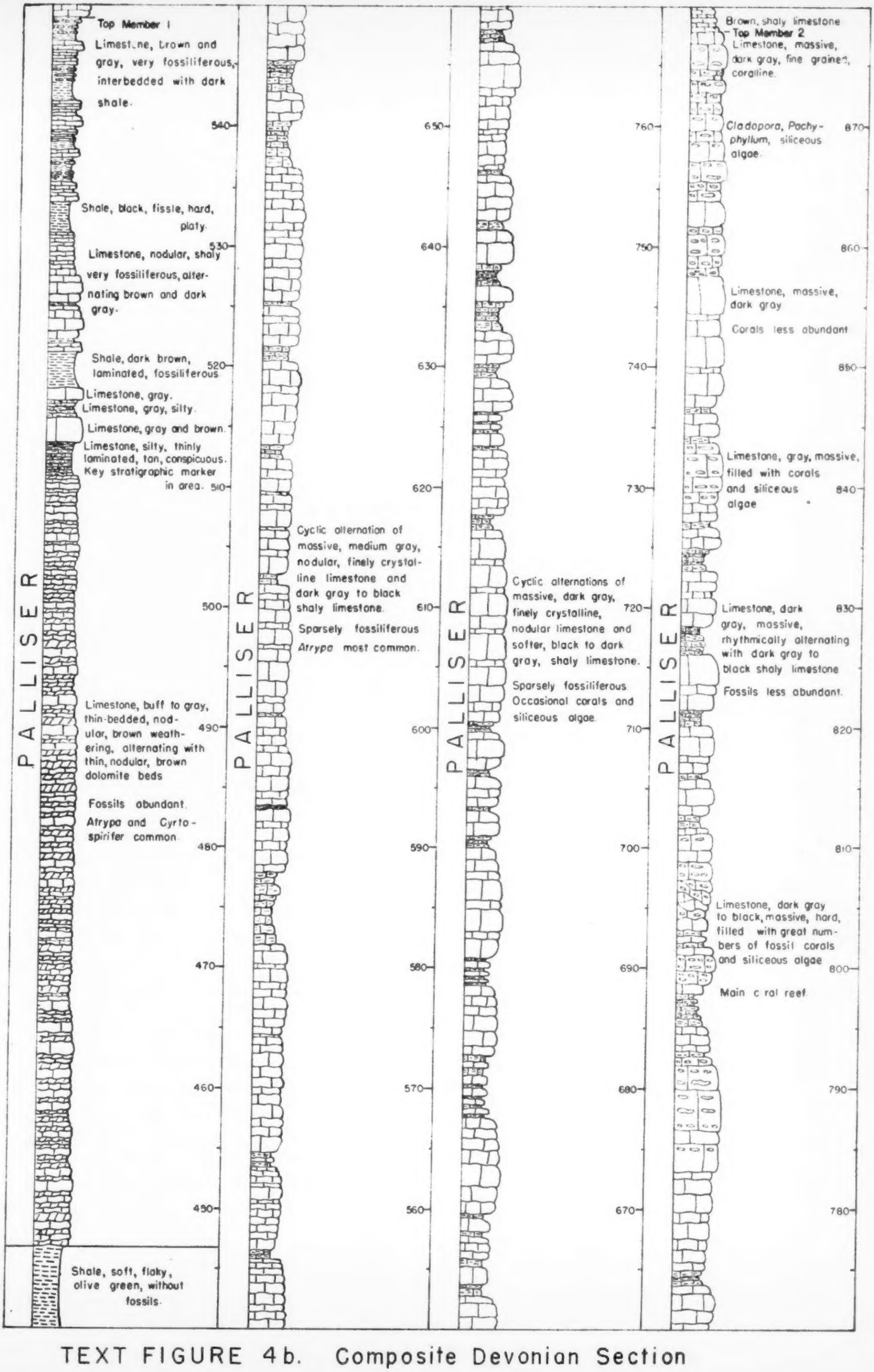
PALLISER FORMATION

The name Palliser was proposed by Beach (1943, p. 15) for the massive, gray, scarp-forming limestone beds that crop out conspicuously beneath the Exshaw shale in the Banff area in Alberta. The distinctive lithologic character of the Palliser formation which is unlike any other in the section exposed in the Canadian Rockies, coupled with its *Cyrtospirifer* fauna, makes it easily recognizable in the area of outcrop. Even more remarkably it maintains this lithologic character from northern Montana to the Wapiti Lake area. Since most sediments undergo rapid facies changes within relatively short distances, it is logical to assume that these sections must lie in the same relative zone with regard to the shoreline of this ancient Devonian sea.

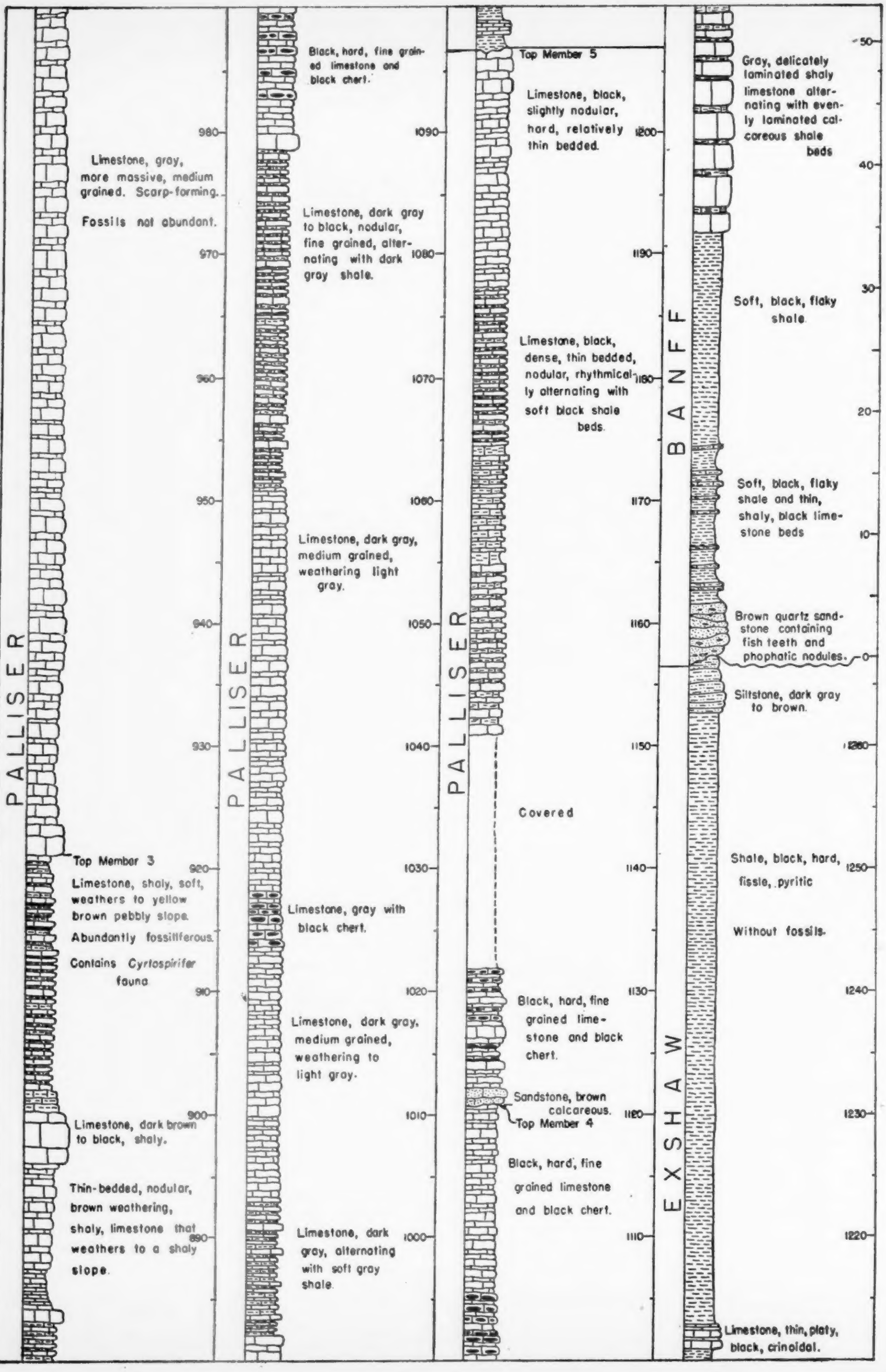
No evidences of erosional unconformity were found on the few observed exposures of the contact between the Palliser and the underlying Fairholme.



TEXT FIGURE 4a Composite Devonian Section



TEXT FIGURE 4b. Composite Devonian Section



TEXT FIGURE 4c. Composite Devonian Section

However, the lithologic change is abrupt and the lower beds of the Palliser are very fossiliferous while no fossils are found in the upper beds of the Fairholme. The occurrence of green shales, interbedded with nodular limestone, in the base of the Palliser suggests that they may be reworked from the underlying Fairholme.

Detailed study of the Palliser formation in the Wapiti Lake area shows it to be composed of six definite members, only part of which maintain lithologic characteristics. The uppermost member in particular may represent a separable formation.

Member 1.—The basal member of the Palliser formation consists of nodular, very thin-bedded, brown-weathering, dark gray, fossiliferous limestone interbedded with soft, green to black, flaky, very fossiliferous, shale beds. One distinctive zone marker, 64 feet above the base, was used consistently throughout the area in determining structure. It consists of 32 inches of light tan, finely laminated, mud-cracked, shaly limestone. Because of its exceptional lithologic character and color, and because it appears throughout the area at the same position in the section it was used as a key marker. The maximum thickness of member one is 75 feet.

Member 2.—The shaly, basal member is succeeded by massive, nodular, gray-weathering, dark gray to black limestone beds more or less rhythmically interbedded with softer, thinner-bedded, colored, shaly limestone beds. Dark colored, algal chert nodules occur at several zones in the upper part of the member. Fossil corals occur throughout the member but are particularly abundant in the upper beds. One bed, 16 feet below the top, is essentially composed of corals. This reef-like coral zone is persistent throughout the area. The maximum thickness of member 2 is 480 feet.

Member 3.—The coralline beds are succeeded by a conspicuous succession of soft, brown-weathering, thin-bedded, nodular, shaly limestone beds that contain excellently preserved *Cyrtospirifer* fossils. These rich brown-weathering, soft, shaly limestone beds weather to a retreating, shaly slope between the massive scarp-forming, gray limestones above and the massive, gray, coralline beds beneath. For this reason they form a key horizon in the middle of the Palliser formation. This member is conspicuously visible from long distances. The maximum thickness of member 3 is 180 feet.

Member 4.—Massive, light gray-weathering, gray to black, nodular, relatively non-fossiliferous limestone interbedded with soft, silty, shale beds follows the brown-weathering member. These beds weather to conspicuous "flat-iron" beds in the South Gap Canyon area. The lower part of the member weathers to light gray; the upper part to black, with sharp demarcation between the two zones. The maximum thickness of the member is 375 feet.

Member 5.—The massive "flat-iron" beds of member 4 are followed by a cyclic sequence of limestones and shales. The sequence consists of thin, hard, nodular, black limestone beds rhythmically alternating with softer, dark gray,

silty limestone beds. The gray, silty layers weather more readily than the harder black layers, giving the exposures a banded appearance. Black chert nodules are present in the upper part. Fossils are rare in this member. The maximum thickness is 210 feet.

Member 6.—Some evidence of disconformity occurs at the base of member six. The basal bed consists of slightly sandy limestone. The remaining beds consist of a cyclic sequence of nodular, dense, hard, black limestone beds rhythmically bedded with softer, laminated, silty limestone beds. A few black chert beds occur in the member.

The maximum thickness of this member can be observed on Rigby Peak. Due to pre-Mississippian erosion, in most other localities the Exshaw shale and parts of this member were removed before Mississippian deposition. In South Gap Canyon only 7 feet of beds are referable to this member.

Fossils occur abundantly in the lower three members of the Palliser formation and in some places in the upper part.

The basal shaly member is prolifically fossiliferous although the number of species is not large. The following forms have been identified: *Phillipsastraea* sp., two species of *Ptychophyllum*, three species of *Atrypa*, *Cyrtospirifer* aff. *C. portae* Merriam, *Spirifer* aff. *S. orestes* Hall & Whitfield, two species of *Gypidula*, *Pugnoides* sp., *Nervostrophia* sp., and *Meristella* sp.

Member 2 is exceptionally fossiliferous, particularly in the upper part. A large part of the fauna has not been identified due mainly to the presence of large numbers of corals that are new. The following forms have been tentatively identified: *Phillipsastraea* sp., *Acanthophyllum* sp., *Spongiophyllum* sp., *Cladochonus* sp., *Ptychophyllum* sp., *Syringopora* sp., *Thamnopora* sp., *Synaptophyllum* sp., *Hexagonaria* cf. *H. percarinata* Sloss, *Hexagonaria* cf. *H. quadrigeminum arcticum* (Meek), *Tenticospirifer* cf. *T. cyrtinaformis*, *Atrypa* sp., and *Gypidula* sp.

The soft, brown, shaly beds of member 3 have yielded the most diversified fauna of the Palliser formation. Corals are conspicuously absent in this part of the section. The following forms have been tentatively identified: *Cladochonus* sp., *Syringopora* sp., *Coenites* sp., *Aparchites* sp., *Productella* sp., *Schuchertella* sp., *Pugnoides* sp., *Cranaena* sp., *Camarotoechia* aff. *C. contracta* (Hall), *Camarotoechia* sp., *Cyrtospirifer* cf. *C. portae* Merriam, *Cyrtospirifer* cf. *C. animasensis* Girty, *Hypothyridina emmonsi* Hall & Whitfield, *Hypothyridina* sp., *Athyris* aff. *A. angelicoides* Merriam, *Bellerophon* sp., *Straparollus* aff. *S. laxus* (Hall), *Murchisonia* sp., and *Floydia* aff. *F. gigantea hackberryensis* (Webster).

Fossils are rare in member 4, the following having been identified: *Cyrtospirifer* sp., *Floydia* sp., and crinoid-stem fragments. *Cyrtospirifer* has also been identified from member 5.

The fauna of the upper member of the Palliser formation also suggests that it should eventually be classed as a separate formation. The basal sandy limestone on Rigby Peak contains numerous linguloid brachiopods, fish teeth, and phos-

phatic concretions. One specimen of *Leiorhynchus* has been found and, from the upper beds, large numbers of specimens of a species of pelecypod tentatively referred to *Leiopteria*.

The presence of *Cyrtospirifer*, *Phillipsastraea*, *Tenticospirifer*, *Hypothyridina*, and *Floydia* places the Palliser formation in the Upper Devonian.

EXSHAW FORMATION

The Exshaw formation rests unconformably on the Palliser and is present only in the North Gap Canyon area. Due to its soft nature it has been removed from most of the area by pre-Mississippian erosion. The Exshaw consists of a few feet of platy, black, crinoidal limestone at the base overlain by black fissile shale and capped with gray-brown claystone. The maximum thickness is 57 feet. No fossils have been found in the Exshaw formation.

Considerable conjecture has arisen among geologists about the age of the Exshaw shale. Since it is overlain in the Wapiti Lake area by black shales of early Mississippian age, the definite presence of both Mississippian and Devonian black shales is established. Whether shales previously referred to the Exshaw are truly Devonian or Mississippian can be determined only by further careful work.

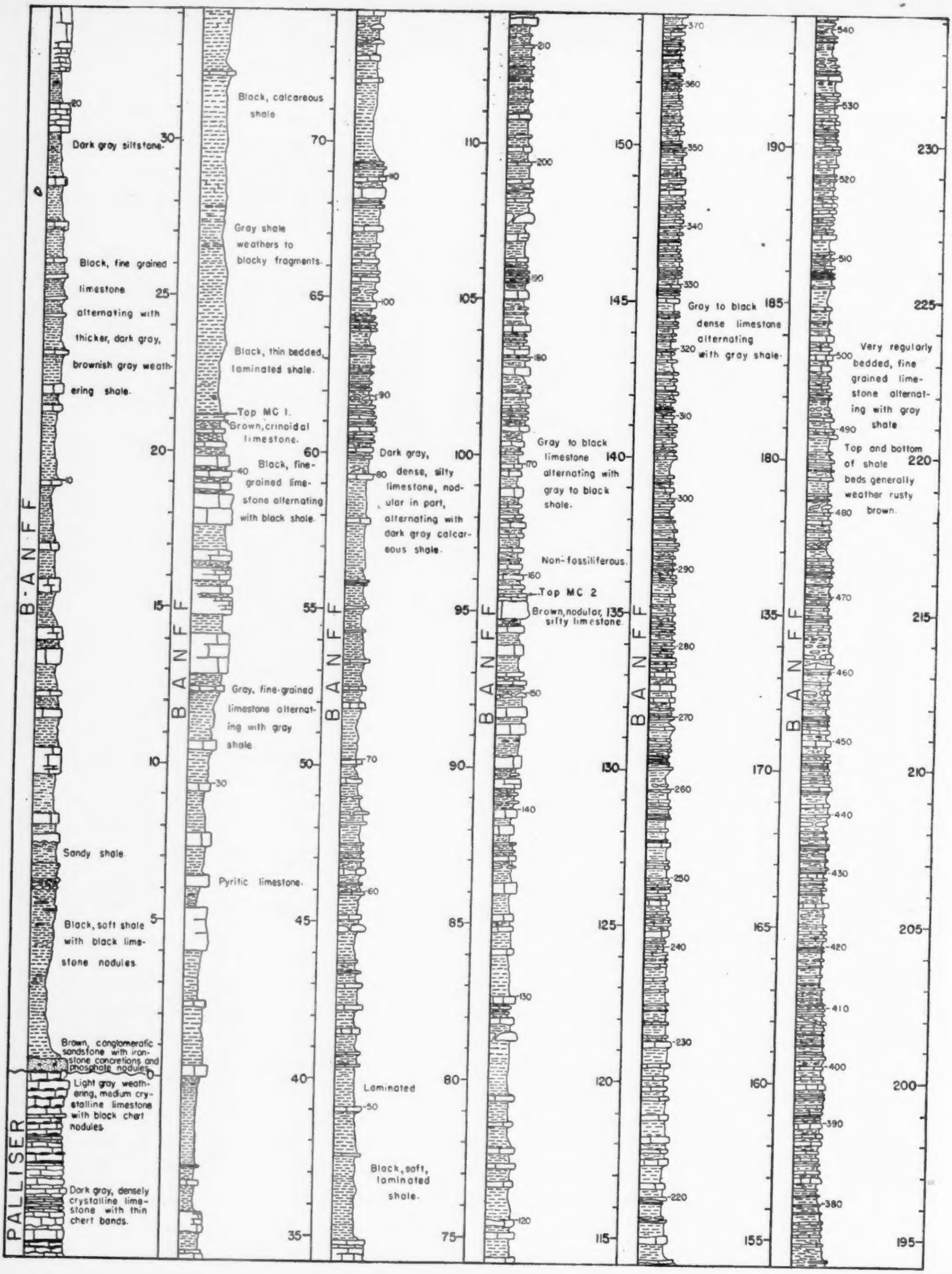
MISSISSIPPIAN ROCKS

In the Wapiti Lake area Mississippian rocks exhibit essentially the same sequence that characterizes their exposure areas in the southern Canadian Rockies and in northern Montana. They consist of shaly, nodular, commonly laminated, fossiliferous limestone beds that grade upward into crinoidal limestones. These basal beds are overlain by much more massive, gray, scarp-forming limestone beds that contain an abundant zaphrentid coral fauna. Massive, gray to brown, scarp-forming, cherty dolomite beds that contain a *Lithostrotion* fauna rest with marked unconformity on the zaphrentid coral-bearing beds.

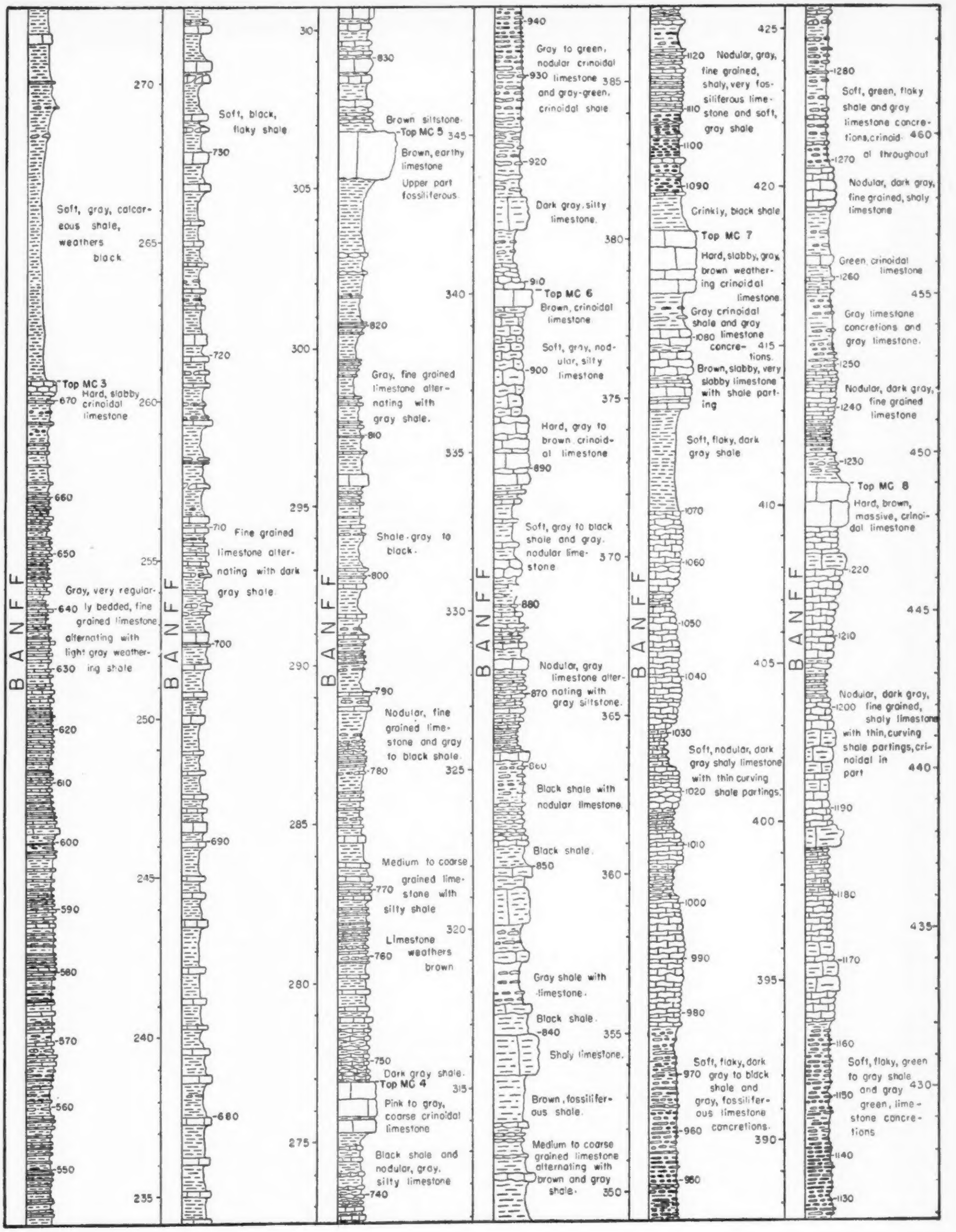
BANFF FORMATION

Warren (1937, p. 456) restricted the Banff formation to the black, shaly limestones between the Exshaw (Devonian) shale and the overlying massive crinoidal limestones which at that time he referred to the Rundle formation. The writers use the term Banff in the same manner in this paper.

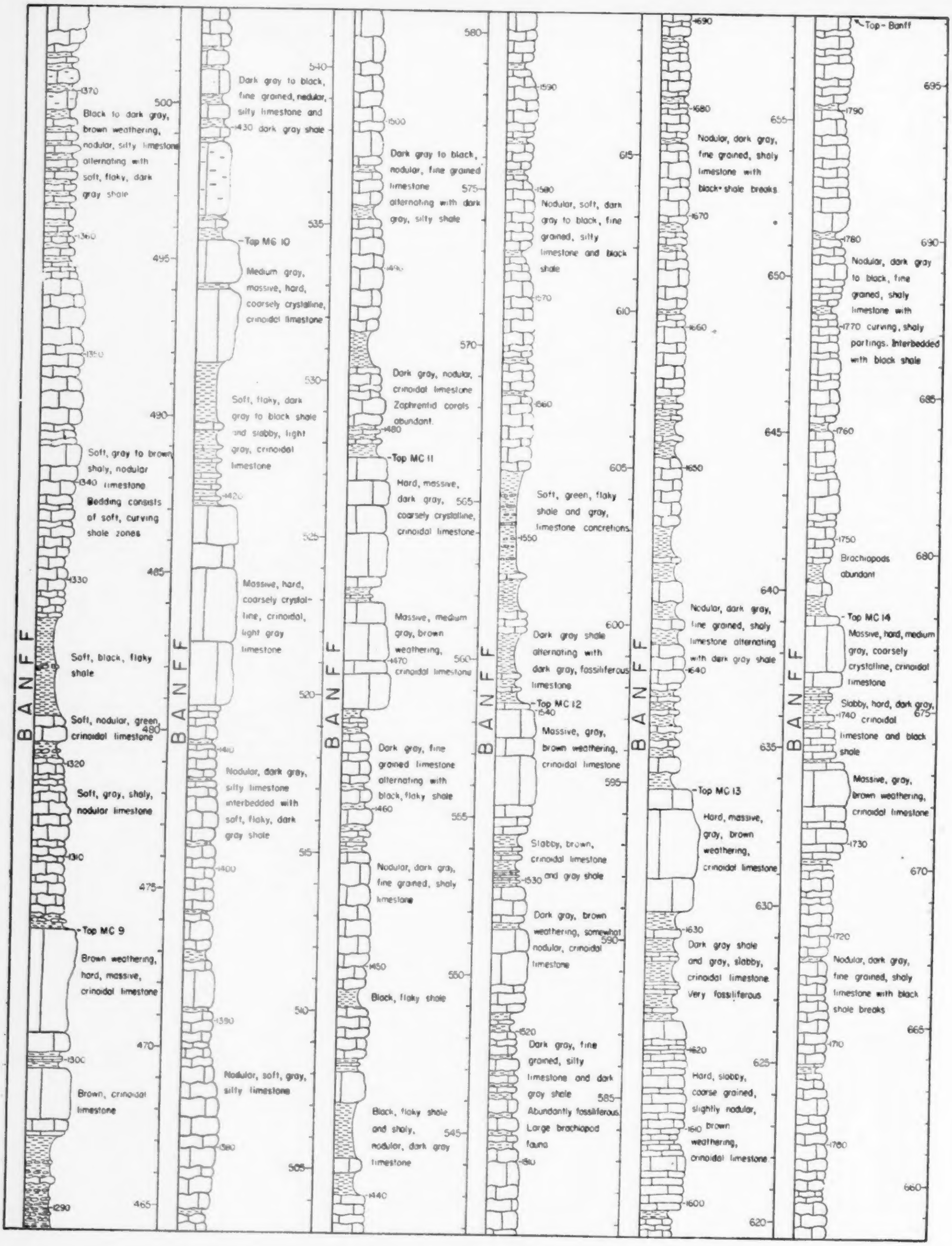
The Banff formation is remarkably cyclic in the Wapiti Lake area. Both minor and major cyclic deposition are represented. Close study, particularly of the megacyclic units, was of great value in correlation in the area. Smaller rhythmic units consisting normally of a shale followed by a thin limestone bed have been numbered in the diagrammed sections. Major cycles, perhaps comparable with the megacyclic units developed in the Pennsylvanian rocks of the Mid-Continent area, have been designated at the top of each major unit in the diagrammed sections by the letter MC and a number. In the lower part of the Banff formation minor laminations very similar in appearance to varves were developed within the minor cycles.



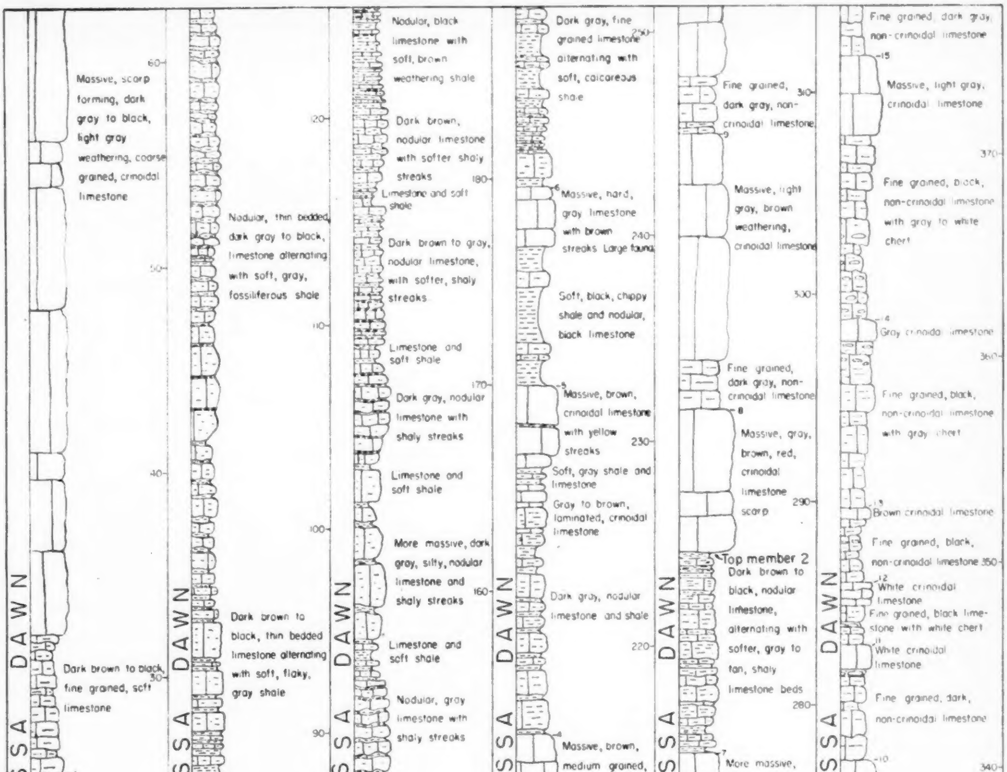
TEXT FIGURE 5a. SOUTH GAP CANYON SECTION



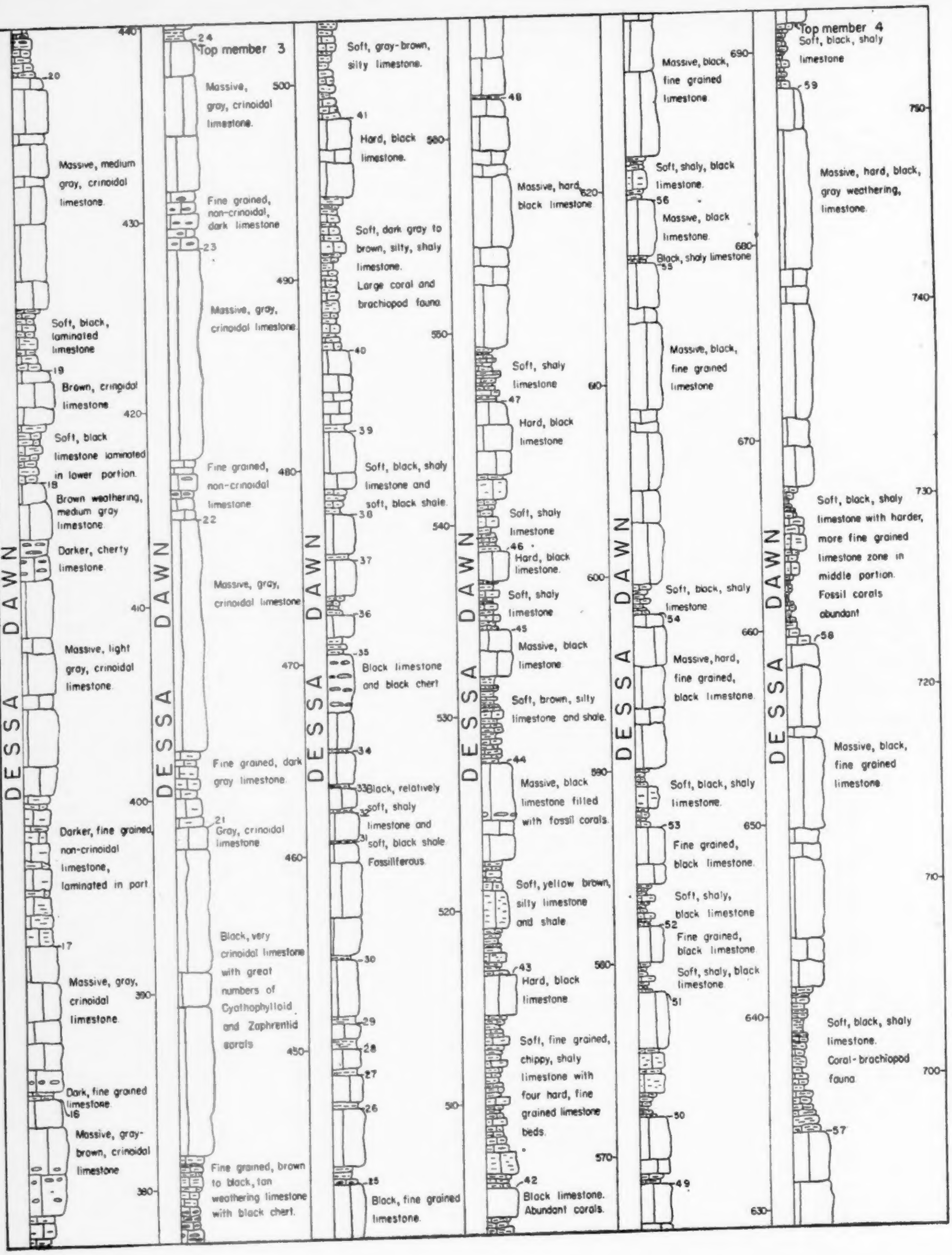
TEXT FIGURE 5b. SOUTH GAP CANYON SECTION



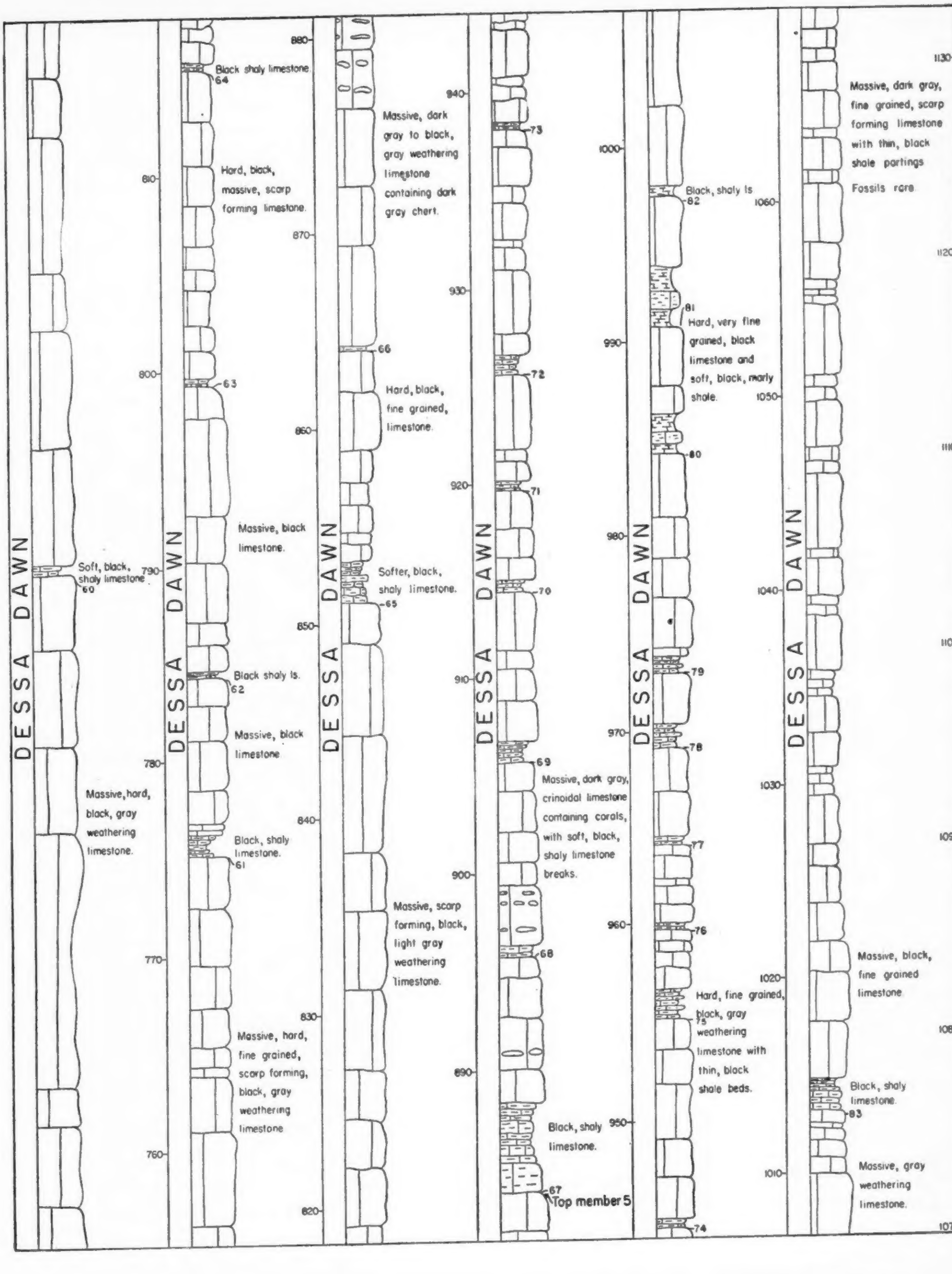
TEXT FIGURE 5c SOUTH GAP CANYON SECTION



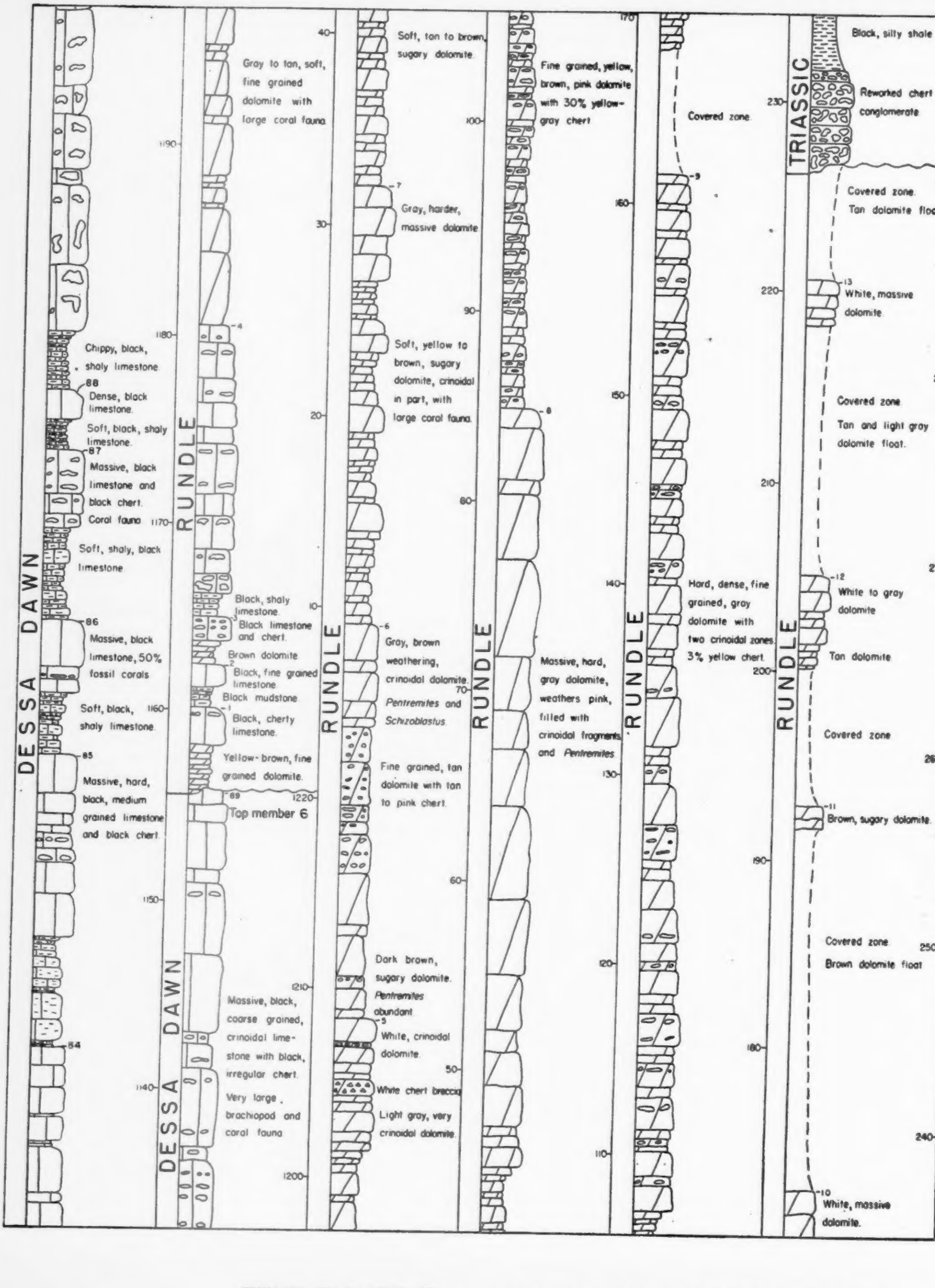
TEXT FIGURE 5d. SOUTH GAP CANYON SECTION



TEXT FIGURE 5e. SOUTH GAP CANYON SECTION



TEXT FIGURE 5f. SOUTH GAP CANYON SECTION



TEXT FIGURE 5g. SOUTH GAP CANYON SECTION

Each megacycle consists of a considerable number of minor alternations of shale and gray shaly limestone followed by more massive, hard, green or brown, crinoidal limestone that generally forms an escarpment. The minor rhythms of shale and shaly limestone form a much greater part of the section. The brown, crinoidal limestone part of the megacycle becomes gradually thicker and more complex upward in the section and the softer shaly part thins. Flat, slabby, evenly bedded, quiet-water limestone and shale alternations characterize a considerable part of the lower Banff and are gradually replaced upward by the more normal, nodular, shaly limestones. This gradual increase in calcareous material and gradual decrease in clastic sediment is interpreted to indicate gradual progressive submergence during the time in which the Banff sediments were being deposited. Fossils are present but scarce in the lower beds of the Banff; they gradually increase upward in the section, and in the upper beds are very abundant.

The Banff formation thins southward, the thickness in South Gap Canyon being 697 feet, in Goat Gap 555 feet, and in Bear Gap only 495 feet. No area was found north of Wapiti River where a complete section could be measured. The diagrammed North Gap Canyon section was faulted so that the upper cycles are missing. Comparison of the cycles that were present north of Wapiti River indicates some thinning in that direction.

Exposures in the Wapiti Lake area were exceptionally excellent so that with sufficient care it was possible to measure and study complete sections in which each bed was exposed. In the field each bed was measured and plotted to scale. Later, attempts were made to match beds throughout the area much in the same manner that varved clays are matched. Lithologic samples were collected from natural units throughout the section and faunas collected wherever they were available. Scales were chosen for diagrammed sections sufficiently large to allow every bed, with the exception of the minor laminations near the base of the Banff formation, to be shown.

The Banff formation exhibits four lithologic members in the area, the basal two of which are relatively thin but continuous. Where exposed, their topographic expression makes them immediately apparent in the field.

Member 1.—The lower member of the Banff formation consists of basal sand and conglomerate followed by fissile black shale. Topographically it forms a retreating, rubble-covered slope.

The Banff rests with marked unconformity on the underlying Devonian surface. A black, brown-weathering, bituminous, quartz sandstone that contains local chert conglomerate beds and is irregularly interbedded with lenses of black, sandy shale generally is present in the basal part of the member. On most exposures the sand beds contain numerous black phosphatic concretions and fish teeth. The basal sands are well developed in Bear Gap, essentially absent in Goat Gap, vary in thickness from 2 inches to 2 feet in South Gap Canyon, and reach a maximum development of slightly more than 5 feet at the head of North Gap

Canyon. The best exposures are in the low pass between Frozen Lake and the north end of North Gap Canyon. Although the basal sands of the Banff formation are too thin to be considered as a possible reservoir rock for petroleum in the adjoining area northeast of Wapiti Lake, they probably thicken in the direction of the source of the sediments. They are stratigraphically and lithologically similar to the Sylamore sandstone that contains some petroleum in the Mid-Continent area.

The Banff formation rests on the eroded surface of the Palliser formation in the area south of Wapiti River, while in North Gap Canyon, less than 3 miles distant, it rests on the Exshaw formation. From such observations it is certain that the basal sands represent a shore facies and are not of the same age in various parts of the area.

The basal sands are followed by delicately laminated, platy, black, pyritic shale. Good exposures are rare, the best being located in the short gullies on the southeast side of South Gap Canyon about midway between the lake and the pass. The maximum thickness of the shale is 9 feet.

Member 2.—The second member of the Banff formation consists of a cyclic sequence of hard, dark, blue-gray, silty limestone beds alternating with softer, dark gray to black, silty shale beds. The limestone beds are sufficiently resistant that the member forms a low rounded scarp in the exposure pattern. This is due to the fact that the member is both underlain and overlain by soft black shale. The limestone beds average less than 6 inches in thickness and the shale units average approximately one foot in thickness. A single 3-inch bed of hard, brown, crinoidal limestone lies at the top of this member in South Gap Canyon. Crinoidal limestones lithologically like this thin bed occur at the top of each megacycle in the Banff formation in the area. Accordingly this crinoidal bed is designated as the top of the first megacycle in the diagrammed section for South Gap Canyon.

Both shale and limestone units in member 2 are delicately laminated in South Gap Canyon. Each lamination is made up of a pair of beds consisting of a very thin, black, shaly unit followed by a thicker, lighter-colored, slightly more calcareous unit. In appearance they are similar to varves. The beds were deposited in close association with marine beds as shown by marine fossils in the same unit in North Gap Canyon and marine fossils in the crinoidal limestone at the top of the member. The following speculation is offered although it has little scientific evidence for support.

If it is assumed that the varve-like beds are seasonal laminations, there is some basis for estimation of the amount of time required for deposition of the Banff formation. A count was made of the pairs of laminations in both shale and limestone units at several areas in South Gap Canyon. In the shale units the maximum number of lamination pairs was 273, the minimum 24, and the average 192. In the limestone units the maximum number of lamination pairs was 22, the minimum 8, and the average 16. The average number of lamination pairs in each cyclic unit was 208. Since 1799 cyclic pairs of beds have been counted in the

Banff formation in the South Gap Canyon area, 1799×208 equals 374,192 years for the accumulation of the Banff sediments.

It is possible that such sediments could have been deposited in a quiet, more or less land-locked arm of the sea, isolated enough from the marine environment to preserve the seasonal laminations, yet not far enough removed to prevent development of the normal cyclic sequence that characterized most of the Banff formation.

Fossils, sparingly present in member 2 in the North Gap Canyon area, are also contained in the single crinoidal limestone bed at the top of member 2 in South Gap Canyon. The following early Kinderhook forms have been identified: *Cyathaxonia* sp., *Chonetes logani* Norwood and Pratten, *Chonetes multicostata* Winchell, *Spirifer biplicoides* Weller, *Spirifer louisianensis* Rowley, and *Ambocoelia* sp.; *Chonetes logani* is by far the most abundantly occurring species.

Member 3.—The rocks in member 3 gradually change facies toward the north so that two differing but related rock types are exhibited in different parts of the area. Every phase of intergradation between the two facies can be observed in the intervening area.

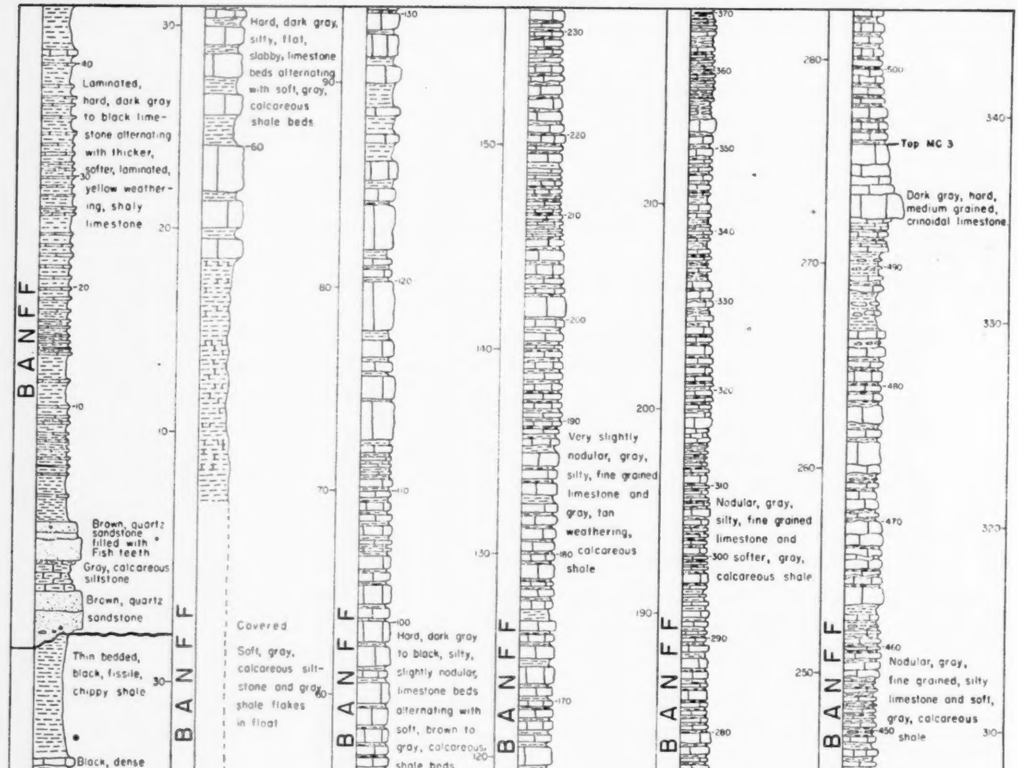
Soft, flaky, black shale ranging between 12 and 19 feet in thickness is present at the base of member 3 at all observed exposures. This shale is interpreted to represent the thick lower half of the first cycle in megacycle two.

In the area south of Wapiti River, member 3 consists mainly of cyclic pairs of thin, slabby, dark gray to black, relatively hard, silty limestone beds and soft, flaky, dark gray to black shale beds. The limestone beds average less than 2 inches in thickness but a few reach a thickness of 14 inches. The shale beds in general are thicker, averaging approximately 7 inches and a few as much as 4 feet. All of member 3 south of Wapiti River is remarkably even-bedded, suggesting deposition in very still water in the absence of current action.

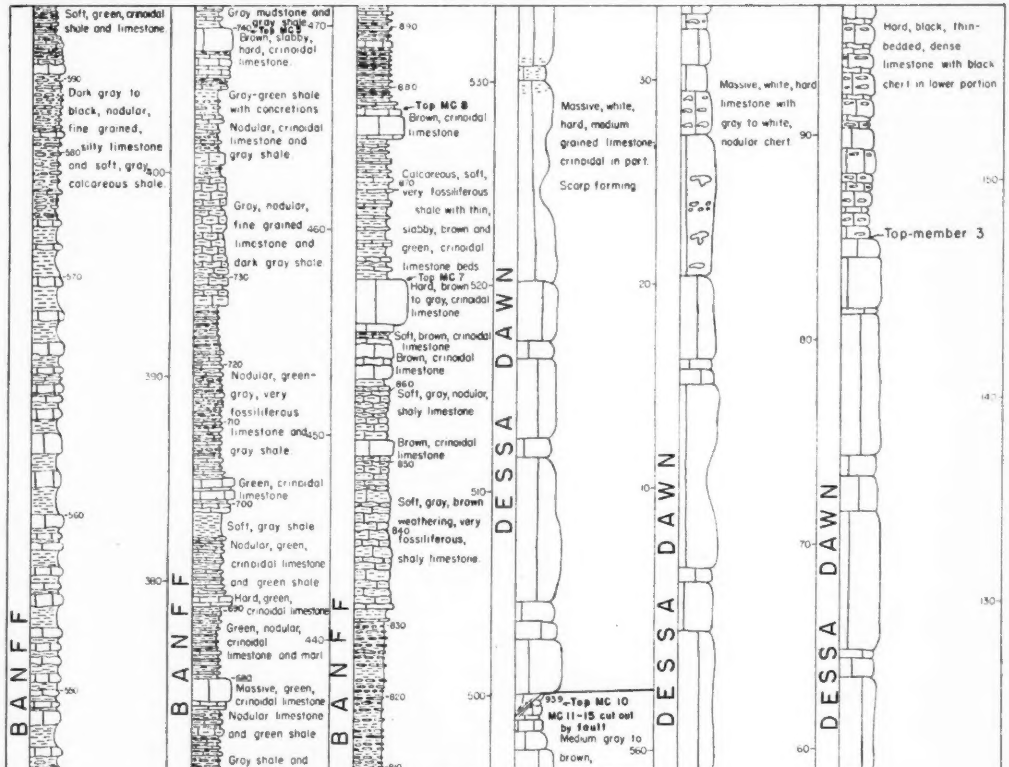
Since member 3 grades into member 4, the contact is arbitrarily chosen at the top of megacycle 4. The shaly limestone beds gradually become more nodular upward in the section and the massive, brown, crinoidal limestone beds that end the megacycle become more prominent. The change to nodular limestone appears much lower in the section north of Wapiti River and all of megacycle 4 lithologically belongs in member 4 in this area.

The massive upper part of megacycle 2 is weakly developed in the area south of Wapiti River. It consists of a conspicuous ledge of massive, brown, soft, silty limestone followed by several of the typical, thin, brown crinoidal limestone beds. The massive upper bed that ends megacycle 3 is even less prominently developed. The brown crinoidal rock type, however, is conspicuous among the soft, gray, silty limestone and shale beds. The massive crinoidal ledge at the top of megacycle four is easily recognized throughout the area.

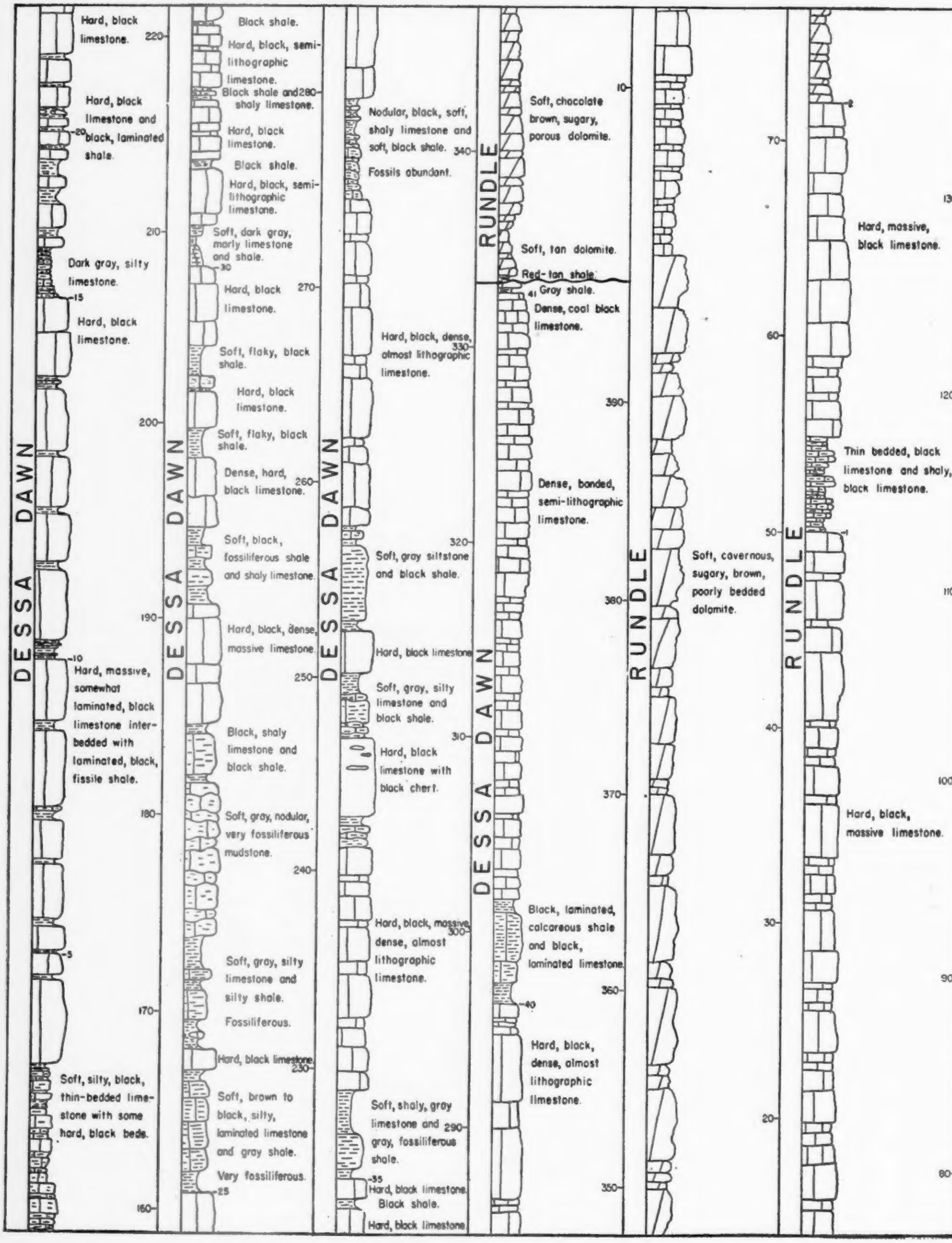
In the area north of Wapiti River all of member 3 except the basal black shale consists of more normal, dark gray, very nodular, shaly limestone with thinner, curved, shaly partings between the nodules. Shale makes up a lesser



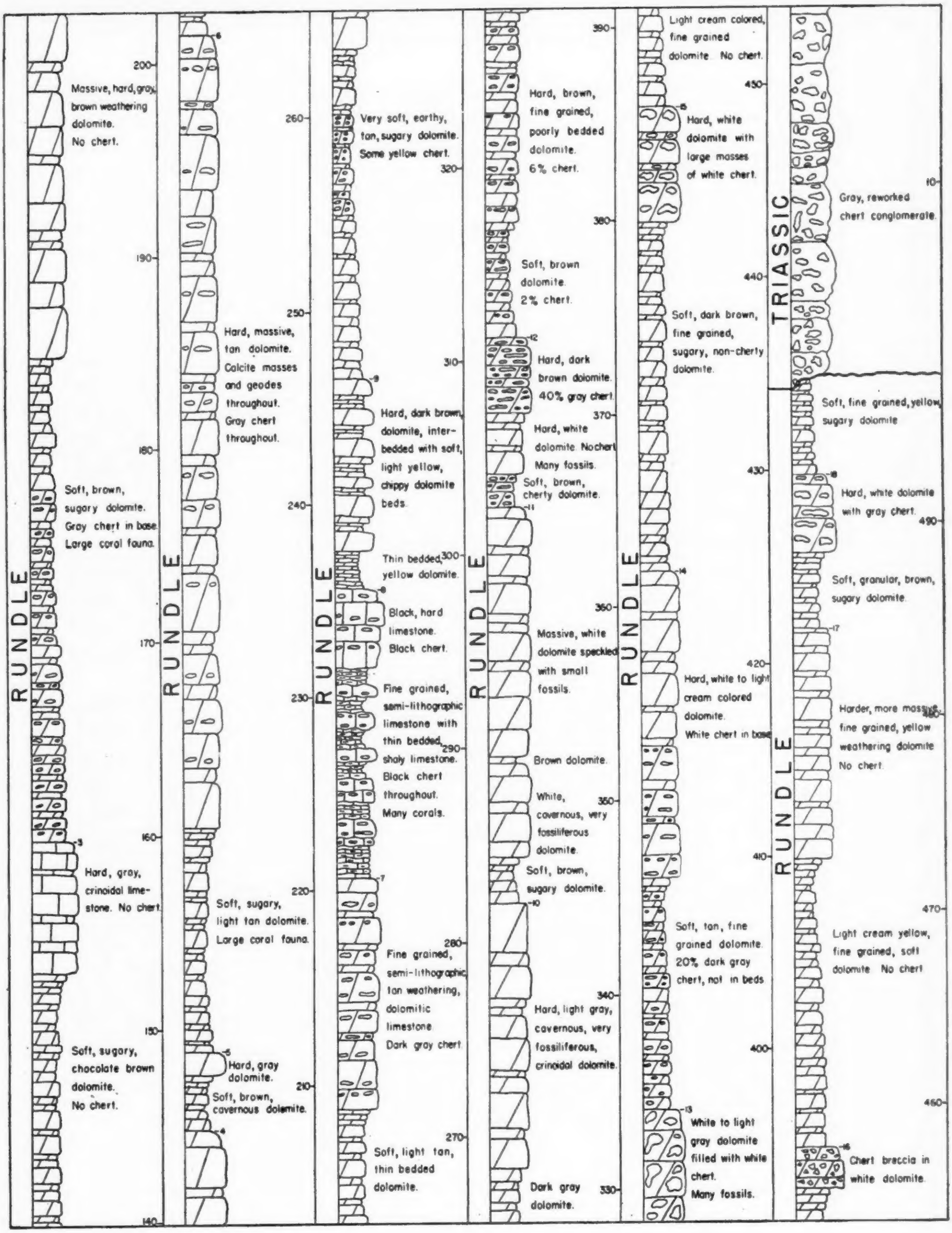
TEXT FIGURE 6a. North Gap Canyon Section



TEXT FIGURE 6b North Gap Canyon Section



TEXT FIGURE 6c. North Gap Canyon Section



TEXT FIGURE 6d. North Gap Canyon, Section

part of the sections and although the limestone beds are slightly thicker the section as a whole is much thinner than in the area south of Wapiti River. The brown crinoidal limestone beds that are present at the top of megacycles 1 and 2 south of Wapiti River have not been identified in the North Gap Canyon section.

North of Wapiti River, fossils occur more abundantly throughout member 3 and are abundant in the upper part. The following species have been identified: *Amplexus coraloides* Sowerby, *Platycrinites* sp., *Decadocrinus* sp., *Dictyoclostus chouteauensis* (Branson), *Rhynchopora cooperensis* (Shumard), *Brachythyris peculiaris* (Shumard), and *Reticularia cooperensis* Swallow.

Member 4.—The upper member of the Banff formation consists of a megacyclic sequence of soft, nodular, shaly limestones followed by massive, hard, brown, crinoidal limestone beds that crop out as conspicuous escarpments. The megacycles also contain minor rhythms that consist of soft, gray, nodular, very fossiliferous, shaly limestone beds which alternate with soft, dark gray to black, fossiliferous shale beds. The softer non-resistant part of several of the megacycles contains shaly beds filled with discontinuous rows of limestone nodules. The lower shaly part of the megacycle in member 3 generally contains several beds of soft, gray, nodular limestone with softer, thin, shale beds that curve around the nodular beds. This lithology is characteristic of early Mississippian rocks in large parts of North America, from the Chouteau of the Mississippi Valley to the Caballero of New Mexico, the Lodgepole of Montana, and the Banff of southern British Columbia.

The massive, scarp-forming, brown, crinoidal limestone that ends each megacycle develops variations in the upper part of the Banff formation. In the South Gap Canyon area, megacycles 7 through 14 with the exception of 8 are characterized by two limestone scarps separated by a conspicuous, fossiliferous, shaly zone that commonly contains thin-bedded, flat, slabby, hard, crinoidal limestone beds. This double nature repeats itself with regularity throughout the upper cycles.

The upper member of the Banff formation is abundantly fossiliferous throughout the Wapiti Lake area. Preservation of fossils in the shaly beds is exceptionally good. A large part of the fauna is new, with many forms filling gaps in the evolution of well known Mississippi Valley species. The following species have been identified.

FAUNA OF BANFF FORMATION, WAPITI LAKE AREA, BRITISH COLUMBIA

Anthozoa

Cyathaxonia tantilla (Miller)
Amplexus coraloides Sowerby
Zaphrentoides sp.
Zaphrentoides centralis (M. E. & H. Sowerby)
Zaphrentis spinulosa (Grove)
Neozaphrentis sp.
Caninia sp.
Caninia cf. *cylindrica* Scouler
Caninia corniculum (Miller)

Caninia sp.
Fasciculophyllum sp.
Bothrophyllum cf. *longisepta* Lewis
Siphonophyllia sp.

Bryozoa

Fenestella sp.
Fenestella sp.

Echinodermata

Platycrinites annosus S. A. Miller
Platycrinites planus Owen & Shumard
Platycrinites cf. *nodostriatus* Wachsmuth & Springer
Platycrinites sp.
Platycrinites sp.
Platycrinites sp.
Dichocrinus delicatus Wachsmuth & Springer
Culmicrinus sp.
Decadocrinus sp.
Eutaxocrinus sp.
Pentremites sp.
Pentremites sp.

Brachiopoda

Chonetes glenparkensis Weller
Schuchertella sp.
Schellwienella inflata (Winchell)
Avonia cf. *sampsoni* Weller
Avonia pustulifera Moore
Productella concentrica Hall
Dictyoclostus chouteauensis (Branson)
Dictyoclostus arcuatus (Hall)
Linoproductus ovatus (Hall)
Echinoconchus sp.
Rhipidomella missouriensis Swallow
Camarotoechia tuta (Miller)
Camarotoechia chouteauensis (Weller)
Rhynchopora sp.
Rhynchopora cooperensis (Shumard)
Dielasma sp.
Dielasma compressa Weller
Composita sp.
Allorhynchus heteropsis (Winchell)
Spiriferina cf. *transversa* McChesney
Spiriferina solidirostris White
Spirifer cf. *gregeri* Weller
Spirifer louisianensis Rowley
Spirifer centronatus Winchell
Spirifer striatiformis Meek
Spirifer albapenensis Winchell
Brachythyris peculiaris (Shumard)
Brachythyris chouteauensis Weller
Syringothyris newarkensis Weller
Cyrtina sp.
Cliothyridina sp.
Cliothyridina tenuilineata (Rowley)
Reticularia sp.
Reticularia cooperensis Swallow
Martinia rostrata Girty
Martinia sp.
Ambocoelia parva Weller

Pelecypoda

Solemya sp.

Gastropoda
Platyceras sp.

Arthropoda
Phillipsia sampsoni Vogdes

Of the 34 species identified all but 9 occur commonly in Kinderhook rocks in the Mississippi Valley area. This is not an adequate analysis of the fauna since Mississippi Valley forms are essentially all that have been well described in North America. Commonly only one or two specimens among a large number are similar enough to be specifically identified with Mississippi Valley forms and the largest percentage of the Wapiti Lake Banff fauna represents forms ancestral to, or divergent from, known described species.

Almost without exception commonly recognized Osage species are missing from the fauna. Exceptional in the fauna are two new species of *Pentremites*, one more than 1½ inches in diameter, and both closely resembling common Chester species.

Comparison of the Banff fauna from Wapiti Lake with faunas in the writers' collections from the Lodgepole formation of Montana and the Caballero formation of New Mexico shows remarkable similarities between many of the new species. On the basis of similarities in fauna, lithologic character, and stratigraphic position the writers do not hesitate to correlate the Banff formation with the Lodgepole formation of Montana and with the Caballero formation of New Mexico.

DESSA DAWN FORMATION

The new name Dessa Dawn is proposed here for the alternating massive, gray, scarp-forming limestone and shaly black limestone that rest on the softer nodular beds of the Banff formation and lie unconformably beneath the dolomitic limestone beds of the Rundle (restricted) formation. The Dessa Dawn formation rests conformably on the underlying Banff formation and the contact between the two is arbitrarily chosen at the base of the first massive gray limestone escarpment. The maximum thickness is approximately 1,350 feet. The type section of the Dessa Dawn formation is located on the northeast face of Dessa Dawn Peak on the southwest wall of South Gap Canyon approximately one mile upstream from the confluence of South Gap Creek with Wapiti River.

The Dessa Dawn formation consists of conspicuous, light gray-weathering, very massive, scarp-forming limestones that alternate in cyclic sequence with soft, dark gray to black, shaly limestone and shale beds. The massive limestone beds form imposing cliffs and the shaly black zones form retreating, rubble-strewn slopes.

Fossils occur in abundance in some parts of the Dessa Dawn, particularly corals which make veritable reefs in some of the beds in the lower part of the formation. However, the Dessa Dawn is far less fossiliferous than the underlying Banff.

Careful analysis shows the massive limestone parts of the Dessa Dawn formation to consist of cyclic alternations of coarse-grained, gray criquina that alternates with very fine-grained, darker, relatively non-fossiliferous limestone. The same cyclic alternation and lithologic features characterize correlative beds in the central part of the Hannan limestone in the Sawtooth Range in Montana.

The Dessa Dawn formation ranges in thickness from a maximum of 1,360 feet in the Goat Gap area to 1,055 feet in the Bear Gap area. It measures only 380 feet in thickness in the North Gap Canyon area due to pre-Rundle erosion and loss of the basal two members due to faulting.

The Dessa Dawn formation is subdivided into six members based on lithologic character and topographic expression. The lower five are topographically well differentiated while the upper one suggests further subdivision, particularly in the Bear Gap area.

No attempt was made to number all of the minor cycles in the Dessa Dawn formation. In the underlying Banff formation each cyclic pair, however small, was given a cyclic number in the diagrammed sections. Cycle numbers were assigned in the Dessa Dawn formation at the top of each prominent, hard, massive, scarp-forming limestone. Minor cycles are excellently developed in the soft shaly members 2 and 4 in much the same manner that they are developed in the Banff formation. It would have been consistent to assign cyclic numbers to each cyclic pair. The cyclic nature of the massive part of the Dessa Dawn formation is much less clearly developed than in the Banff formation.

The massive, brown, crinoidal limestone beds that end each megacycle of the Banff formation gradually thicken upward in the Banff formation and in megacycle 14 are definitely lighter-colored. Since there is no unconformity between the Banff and Dessa Dawn formations, member 1 of the Dessa Dawn might be interpreted to represent the massive crinoidal end of megacycle 15 of the Banff formation. If this interpretation is correct, members 2 and 3 of the Dessa Dawn formation would represent megacycle 16, members 4 and 5 megacycle 17, and member 6 megacycle 18. Another interpretation is suggested by the assignment of cycle numbers in the diagrammed sections. Future work may clarify interpretation.

Member 1.—The lower member of the Dessa Dawn formation crops out as a bold escarpment. It consists of massive, gray, light gray-weathering, crinoidal limestone with at least two zones of thinner-bedded, darker, fine-grained, non-crinoidal limestone. The member thins in a short distance northward along the wall of South Gap Canyon and has not been identified in the area north of Wapiti River. Member 1 is 77 feet thick in South Gap Canyon, 105 feet thick in the Goat Gap area, and reaches maximum thickness of 115 feet in the Bear Gap area.

Fossils other than fragmental crinoid remains are rare in the basal member of the Dessa Dawn formation. Corals occur sparingly; *Zaphrentoides* sp. and a species of *Caninia* have been identified.

Member 2.—Dark gray to black, thin-bedded, nodular, shaly limestone al-

ternating with soft, flaky, calcareous shale beds rests on the basal massive limestone beds. Lithologically this member is similar to the softer parts of the upper megacycles in the Banff formation. Fossils are less abundant than in the Banff but far more abundant than in the gray massive limestone beds. The following forms have been identified: *Zaphrentoides* sp., *Caninia* sp., *Syringopora* sp., *Platycrinites* sp., *Pentremites* sp., *Dictyoclostus arcuatus* (Hall), *Spirifer platynotus* Weller, and *Spirifer striatiformis* Meek. Member 2 is 210 feet in thickness in South Gap Canyon, 330 feet in thickness in the Goat Gap area, and is only 77 feet in thickness in the Bear Gap area. Member 2 may be seen to pinch out entirely along the middle part of the west wall of South Gap Canyon. In this case the massive gray limestones of member 1 are followed directly by the massive limestones of member 3. No evidence of unconformity has been found at this contact.

Member 3.—Member 3 consists of very massive, gray, light gray-weathering, somewhat cherty limestone that forms a very imposing escarpment. Detailed analysis of the massive limestone escarpment shows a cyclic sequence of massive, light gray to brown, medium to coarsely crystalline coquina alternating with thinner-bedded, fine-grained, dark gray to black, non-crinoidal limestone. The lower, less resistant part of cycle 8 has been classed with member 2 and the massive upper bed of cycle 8 makes the basal ledge of member 3. Light gray to white nodular chert is present, particularly in the middle part of this member. The exposures of member 3 in the North Gap Canyon area were so precipitous that no attempt was made to differentiate the cycles within the member. Member 3 is 216 feet in thickness in South Gap Canyon, 165 feet in thickness in Goat Gap, 162 feet in thickness in Bear Gap, and 147 feet in thickness in North Gap Canyon.

Fragmental fossil crinoid remains occur in great abundance in member 3 and with the exception of corals no other fossils have been found. The basal 5 feet of member 3 contains a profusion of corals as far as numbers of individuals are concerned. In parts of the bed, corals are entwined in reef-like proportions. *Caninia* is by far the most abundantly occurring form with *Zaphrentoides* next in abundance. The following forms have been identified: *Amplexus* sp., *Caninia cylindrica* Scouler, *Caninia callophylloides* (Holtedahl), *Caninia* sp., *Bothrophyllum* sp., *Zaphrentoides* sp., *Zaphrentoides* sp., *Syringopora* sp., and *Siphonophyllia* sp.

Member 4.—Soft, dark gray to black, thinner-bedded, shaly limestone beds that alternate with soft, thin-bedded, black, calcareous shales make up member 4. Because of the soft nature of these beds they generally form a retreating, rubble-covered slope. The beds are perfectly cyclic throughout. The more resistant black limestones become increasingly more prominent in the upper cycles of the member. Member 4 reaches maximum thickness of 249 feet in the North Gap Canyon area, is 238 feet thick in South Gap Canyon, is 210 feet thick in the Goat Gap area, and exhibits its thinnest development of 195 feet in the Bear Gap area at the south.

Fossils are not abundant in member 4. Soft shaly limestone beds such as these

in underlying strata are generally very fossiliferous. Crinoidal fragments are common throughout the member and two beds contain large numbers of specimens of a small species of *Zaphrentoides* and *Cyathaxonia*. The following forms have been identified in a very shaly bed near the top of the member in the Goat Gap area: *Zaphrentoides* sp., *Cyathaxonia* sp., *Syringopora* sp., *Rhipidomella jerseyensis* Weller, *Spirifer platynotus* Weller, *Composita* sp., *Platycrinites* sp., *Pentremites* sp. The *Pentremites* is similar to the smaller species that is found in the underlying Banff strata.

Member 5.—Very massive, dark gray to black, light gray-weathering, scarp-forming limestone with a few very minor black, shaly limestone breaks characterizes member 5. These beds form a massive, imposing escarpment that generally overhangs the softer black strata of member 4. Chert is ordinarily absent in this member although a few lenses of nodular gray chert are found in the South Gap Canyon area. The hard massive members of the cycles in member 5 do not have the masses of fragmental crinoidal material that is present in the equivalent beds in member 3 Member 5 is 191 feet thick in South Gap Canyon, 202 feet thick in the Goat Gap area, and 203 feet thick in the Bear Gap area. Member 5 is not present in North Gap Canyon due to pre-Rundle erosion. The Rundle formation rests on member 4 in that area.

Fossils are rare in member 5. Corals occur sparingly, *Cyathaxonia*, *Zaphrentoides* sp., and *Caninia* sp. having been identified.

Member 6.—All beds between the massive, scarp-forming limestones of member 5 and the Rundle contact are included in member 6.

In the South Gap Canyon area several zones of soft, black, shaly limestone beds seem to be present between massive, scarp-forming limestones. This lithologic character changes gradually toward the south so that in Bear Gap section soft black shaly limestone beds are followed by massive, scarp-forming limestone beds which have the appearance of a single additional megacycle.

In the South Gap Canyon area twenty-two cyclic alternations of massive, hard, black, gray-weathering, scarp-forming limestone and soft, black, shaly limestone are present in this member. The massive, scarp-forming limestone at the top of cycle 84 makes a conspicuous white escarpment and suggests correlation with the massive scarp-forming limestone developed in the upper part of member 6 in the Bear Gap area. Black chert occurs abundantly in the massive part of cycles 85, 86, 87, and 89. Member 6 is 274 feet in thickness in South Gap Canyon, 340 feet thick in the Goat Gap area, and 308 feet thick in the Bear Gap area. It is not present in the North Gap Canyon area due to pre-Rundle erosion.

Several zones in member 6 are very fossiliferous as far as numbers of individuals are concerned but the number of species represented in the fauna is very limited. The following forms have been identified: *Amplexus* sp., *Caninia cylindrica* Scouler, *Caninia* sp., *Pseudouralina* sp., *Syringopora* sp., *Zaphrentoides* sp., *Spirifer platynotus* Weller, *Composita* sp., and *Straparollus* sp.

The Dessa Dawn formation occupies the stratigraphic position normally

occupied by rocks of Osage age in the Mississippi Valley area and in southwestern United States. Rocks, undoubtedly correlatives of the Dessa Dawn, in the Bridger, Tobacco Root, and Little Belt mountains in Montana have been referred to the Osage by Deiss (1933, p. 45). Rocks identical in stratigraphic position and similar in lithology in the Hannan limestone in the Sawtooth Range have been referred to the Osage by Sloss and Laird (1945, chart).

During the last 5 years extensive collections of fossils have been made by the writers from Mississippian rocks throughout Montana. In none of these collections have typical Osage genera or species been found, although there are many species that occupy positions in the scale of evolution mid-way between Mississippi Valley Kinderhook species and true Osage species. In the Montana area, forms such as *Spirifer grimesi*, *Spirifer rowleyi*, and *Dictyoclostus fernglenensis* have not been found.

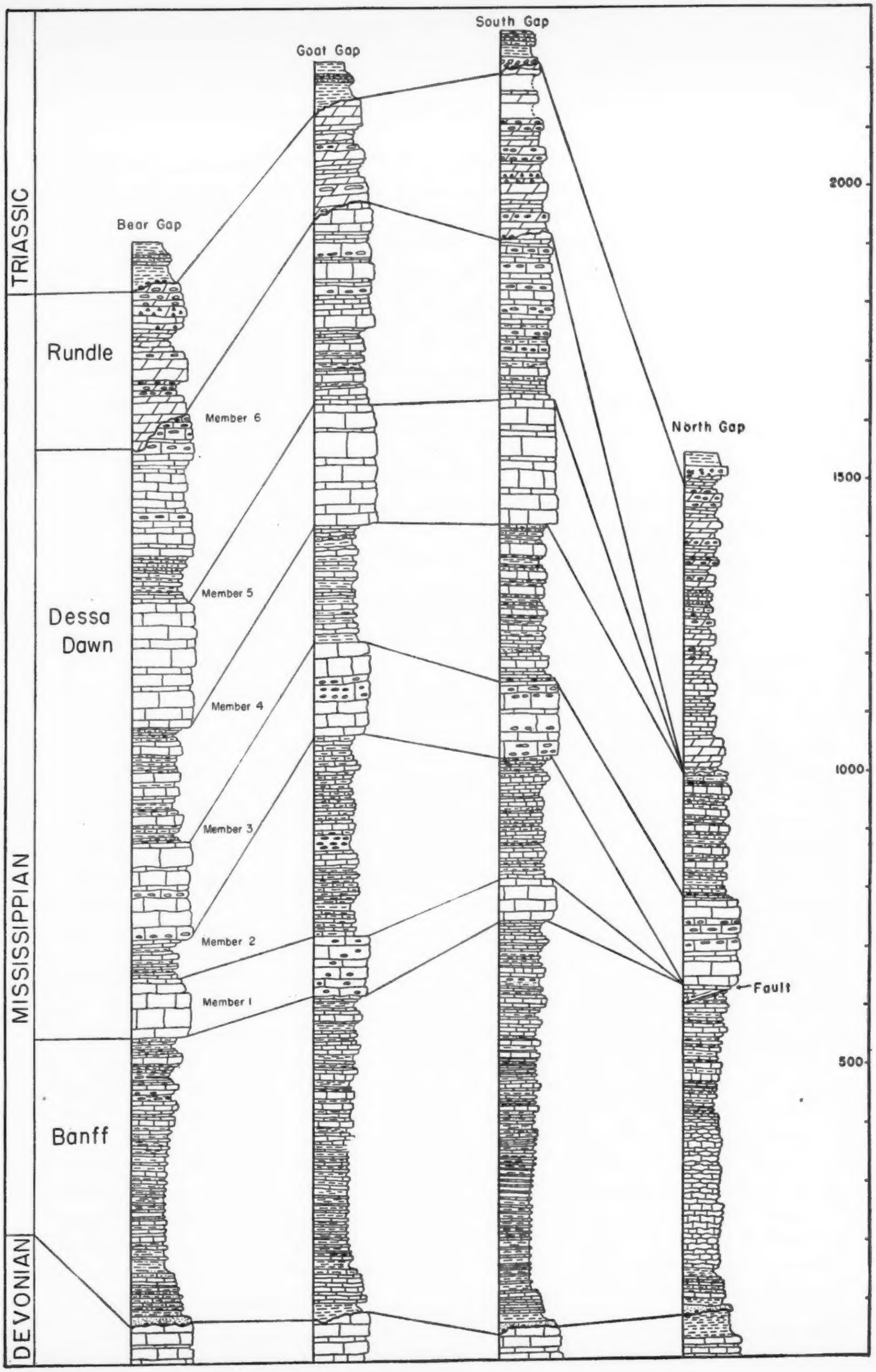
The crinoid fauna from the Montana localities consists predominantly of *Rhodocrinites*, *Cactocrinus*, and *Platycrinites* with only Kinderhook species represented. On the basis of such observations, Laudon (1948, p. 301) suggested that the beds heretofore placed in the Osage were of late Kinderhook age and more closely represent beds of the Z zone in the European section.

Subsequent work in southern British Columbia during the summer of 1948 in the Crowsnest area, the Banff area and in Jasper Park has partly clarified the problem of correlation. Exceptionally excellent faunas were collected in the Sunwapta Pass area in British Columbia during the summer of 1948 where a very thick Banff section was studied. A thick section of beds correlative with the Dessa Dawn rests on the Banff formation at Sunwapta Pass and the whole section from the base of the Banff to the top of the Dessa Dawn equivalents is exceptionally fossiliferous. Fossils found in the highest ledges of this section more closely approach Osage species than any the writers have yet found in this part of the Rocky Mountains. *Spirifer rowleyi* and *Spiriferella plena* are present in the fauna.

Analysis of the Dessa Dawn fauna helps little in solving the problem of the age of these massive crinoidal beds so widespread in western North America. Of the few species identified both Kinderhook and Osage species are represented in nearly equal number.

RUNDLE FORMATION

The writers believe that the name Rundle as originally proposed by Kindle (1924, p. 123) included all of the beds of Mississippian age above the Banff formation as used in this paper. There is considerable variation of opinion among workers to-day about the exact limits of the originally defined Rundle formation. In this paper the name Rundle is restricted to the dolomitic limestone beds containing the *Lithostrotion* fauna which is believed to be found only in the upper part of the originally defined Rundle formation. The writers' interpretation of the Rundle formation is based on the following reasons. A marked hiatus occurs at the base of the Rundle formation as defined in this paper; the lithologic



TEXT FIGURE 7. Correlation Mississippian Sections

character of the underlying Dessa Dawn formation is markedly unlike that of the Rundle formation; a long continuing cyclic sequence is interrupted at this contact; the fauna of the Rundle has Meramecian affinities and the fauna of the Dessa Dawn is believed to be late Kinderhook in age; and this three-fold division of Mississippian rocks fits all observed sections of Mississippian rocks, studied by the writers, in British Columbia, Alberta, and Montana.

The Rundle formation consists predominantly of soft, brown, sugary, porous, cherty, dolomite beds in the Wapiti Lake area. These soft, brown, dolomite beds alternate with hard, white to buff, porous, pure dolomite beds. Several minor limestone beds are present in the lower part of the section, but none of the beds is massive, or hard, like the underlying Dessa Dawn.

The thickness of the Rundle is variable because of extensive erosion on the underlying surface and also because of pre-Triassic erosion on the upper surface. It reaches its maximum thickness of essentially 500 feet in the North Gap Canyon area where it has been deposited in a valley cut into the Dessa Dawn surface. It is 290 feet thick in South Gap Canyon, 280 feet thick in Bear Gap, and 192 feet in thickness in the Goat Gap area.

Eighteen alternations between the soft, brown dolomite beds and the hard, light-colored, massive dolomite beds, have been identified in the North Gap Canyon area. It is probable that cycles 8 and 9 represent several cycles instead of the single unit as diagrammed in the North Gap Canyon section. Gray to yellow chert appears in both parts of the cycle. The brecciated chert in the top of cycle 16 is conspicuously different from other beds and has served as a key marker throughout the area. It has been traced down from the North Gap Canyon area to the shores of Wapiti Lake, recognized in its anticipated position immediately across the lake, and traced well past South Gap. This chert breccia appears in the upper member of cycle 5 in the South Gap Canyon area. Only 48 feet of Rundle strata are present between this chert bed and the Rundle-Dessa Dawn contact in the South Gap Canyon area. Strata 457 feet thick are present between this chert and the Rundle-Dessa Dawn contact in the North Gap Canyon area. Since these areas are less than 3 miles apart some concept of the amount of erosion on the Dessa Dawn surface can be obtained. Strata aggregating 42 feet are present between this chert and the Triassic contact in North Gap Canyon, and strata 244 feet thick occur in the similar position in South Gap Canyon.

The writers' interpretation of extensive erosion between the Rundle and Dessa Dawn with marked relief developed within such short distances will be questioned. There are certainly extra beds in the base of the Rundle in the North Gap area. It is also certain that the Rundle rests on member 4 of the Dessa Dawn on the south face of Pamela Peak. Since this is a heavily faulted area, it is not clear that this contact is not a fault contact. The writers have found evidence of relief at this contact throughout Alberta and Montana but nowhere have they found evidence of as abrupt relief on the surface as is suggested between the North and South Gap Canyon areas.

Fossils are abundantly present in the Rundle formation, particularly in the upper part. Most common are corals which weather from the dolomites as silicified specimens. The following species have been identified: *Diphyphyllum breviseptatum* Yoh, *Diphyphyllum mutabile* Kelly, *Caninia* cf. *kokscharowi* Stuckenberg, *Lithostrotion* sp., *Lithostrotion* sp., *Syringopora* sp., *Spirifer logani* Hall, *Spirifer* sp., *Dictyoclostus* sp., *Pentremites conoideus* Hall, and *Pentremites* sp. Crinoidal remains are also abundant in the limestones and dolomites.

Analysis of this fauna suggests a Meramec age for the Rundle formation. This stratigraphic placement is based on meager evidence since the range of *Lithostrotion* is not well known and since species of *Pentremites* very similar to Chester forms occur as low as the upper part of the Banff formation in this area.

TRIASSIC ROCKS

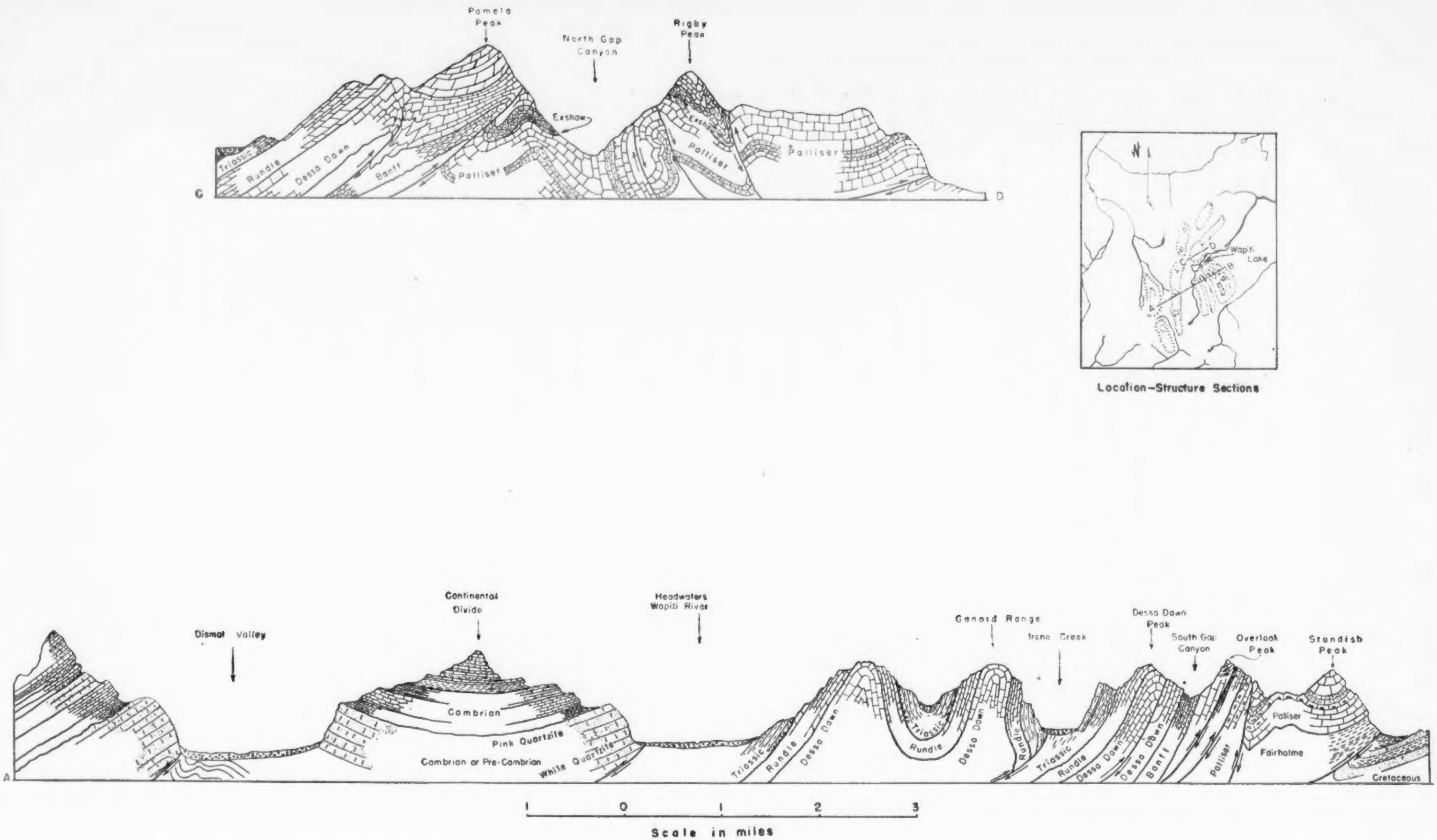
No attempt was made to study the Triassic rocks in any detail. They are excellently exposed along both shores of Wapiti Lake where they stand in steep cliffs. They consist of a cyclic sequence of soft, black silty shale beds alternating with more massive, harder, finely laminated, black, shaly limestone beds. Fossils are not abundant but a few poorly preserved ammonites were collected and one zone containing abundant specimens of *Halobia* was found. The lower beds particularly those just above the contact contain fragments of ganoid fishes throughout the Wapiti Lake area. On the steep slope above Fossil Fish Lake in the Ganoid Range large numbers of excellently preserved specimens of ganoid fishes were discovered. One specimen measured more than 28 inches from dorsal to ventral through the pectoral region. The fossil fishes in this area weathered from flat, thin-bedded, black, laminated, shaly limestone beds overlying the Rundle-Triassic contact.

Since these Triassic rocks are soft they crop out most commonly in the valley areas. The Triassic slopes are ordinarily grassy and in many places the contact between the bare Rundle limestone and the grassy Triassic slopes could be plainly seen for miles along the mountain front.

STRUCTURE

Wapiti Lake is approximately 3 miles southwest of the overthrust front of Paleozoic rocks in this area. The structure is relatively simple and consists of a series of tightly folded thrust-fault blocks. The general structure of the area trends approximately N. 48° W. Paleozoic rocks of Devonian age are overthrust onto Cretaceous rocks that dip rather steeply southwest. The Cretaceous structures northeast of the overthrust front, north of Wapiti River, have more than 1,000 feet of relief on the southwest-dipping flank.

The structure is generally more complex in the area southwest of the overthrust front and becomes gradually less complex southwestward at least to the limits of the area considered by this paper. Since Cretaceous rocks are involved in the structures the time at which the deformation of the area was completed was at least post-Cretaceous.



TEXT FIGURE 8. Diagrammatic Structure Sections Across Area

During the latter part of the field season a 9-day pack trip was taken on foot southwestward across the continental divide to the large ice fields in this area. Our advanced camp was set up in the valley at the foot of the peaks on which the ice fields are located. This valley was tentatively designated as Dismal Valley because the heavy precipitation made working conditions unpleasant. Reconnaissance trips into the surrounding mountain area were taken from this valley. The ranges on both sides of Dismal Valley (Fig. 8, structure section *AB*) consist of thrust blocks in which competent, massive quartzites form the base of the mountain, while the peaks consist of softer Cambrian limestones, shales, and sandstones.

The structure of the Ganoid Range and of the two ranges southwest of the Ganoid Range (Fig. 8, structure section *AB*) was reconstructed from hasty reconnaissance observations made on this pack trip. The structure shown in structure section *AB* northeast of the Ganoid Range was worked out much more carefully and in much greater detail since this was the area of concentrated work during most of the field season.

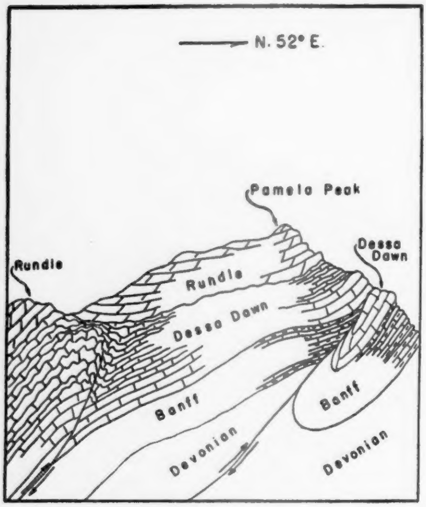
Two directions of faulting are present in the area. Most of the faults are thrusts whose strike is parallel with the regional structure. At least two faults cross the regional structure at high angles within the area studied.

The eastern Paleozoic boundary fault has been determined only from structural relations and the actual fault is not exposed in the area. North of Wapiti River, the rocks east of the boundary fault were traversed on an emergency pack trip back to Grande Prairie. Here the Devonian Fairholme shale dips southwest at a relatively low angle. Less than $\frac{1}{4}$ mile down the same slope, in the valley of Anne Creek, Cretaceous sandstone dips at a slightly greater angle in the same direction. The Fairholme shale crops out with a similar attitude on the northeast face of Standish Peak but the rocks east of this area were not studied.

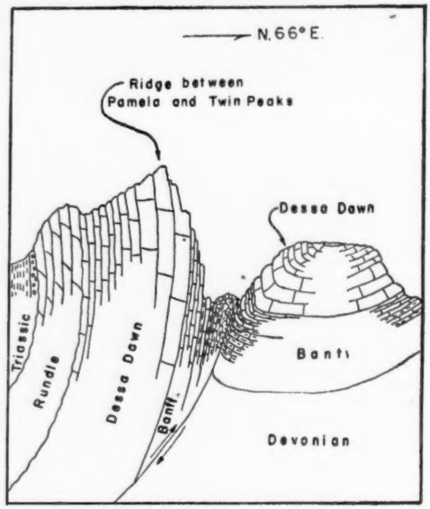
The structure of the area south of Wapiti River can best be understood by a detailed description of each of three topographic ridges that lie between the Ganoid Range and the Paleozoic boundary fault. The easternmost ridge, on which Standish Peak is situated, consists of an asymmetrical syncline, with a small secondary thrust fault west of the apex of the ridge and trending parallel with it.

The valley occupied by Caribou Creek is synclinal in structure, with a small anticlinal fold paralleling the foot of Standish Ridge on the northeast side of the valley, and a small anticlinal structure paralleling the base of Overlook Peak Ridge on the southwest. Static Peak at the south end of Caribou Creek Valley is formed by a tight syncline with the uppermost part of member 5 of the Palliser formation forming the highest point of the peak. Fairholme shale forms the low gap between Static Peak and Standish Ridge. Fairholme shale also forms the gap between Static Peak and Renie Peak but the structure of this gap is complicated by two faults through the gap parallel with the regional structure.

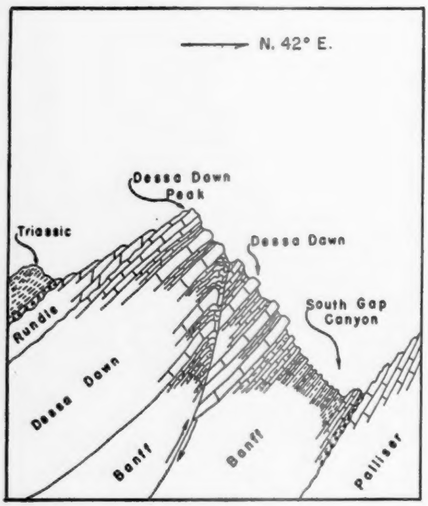
The prominent ridge that trends southeastward from Wapiti River, on which



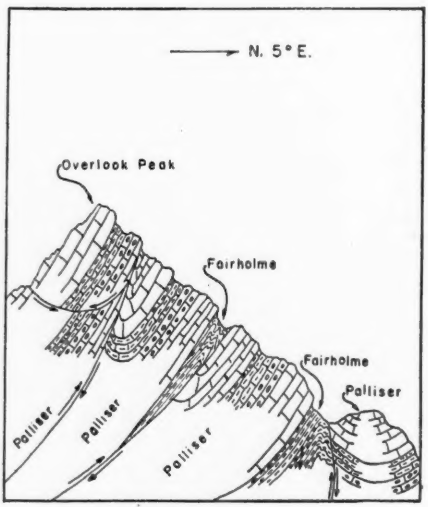
TEXT FIGURE 9a
Diagrammatic Structure
Pamela Peak Area



TEXT FIGURE 9b
Diagrammatic Structure
Pamela---Twin Peaks Area



TEXT FIGURE 9c
Diagrammatic Structure
Dessa Down Peak Area



TEXT FIGURE 9d
Diagrammatic Structure
Overlook Peak Area

TEXT FIGURE 9. Diagrammatic Structure Sections

Overlook Peak is located, consists entirely of Devonian rocks. Three thrust faults cross this ridge parallel with the regional structure in such a manner that parts of the Devonian section are repeated four times. On the northwest face of the mountain two of the faults, with accompanying drag folds, are plainly visible from Wapiti River. The third and easternmost is heavily bush-covered on the northwest face, but can be easily studied where it crosses the northeast spur of Overlook Ridge. This fault crosses from the Wapiti River Valley into Caribou Creek Valley over this spur. The fault plane is exposed and accompanying drag folds are well displayed in the small saddle that has been developed along the fault plane (Fig. 9d). The Palliser section is essentially duplicated by the westernmost of these three faults. The soft, shaly, basal member of the Palliser is in contact with the massive, white limestones of member 4 on the northwest face of the mountain.

An exceptional fault is developed near the top of Overlook Peak. The actual fault plane is excellently exposed and can be traced from South Gap, along the west side of Overlook Peak, around the face of the peak and finally down into Caribou Valley. The fault represents a clear case of underthrusting; with the underlying thrust block displaced northeastward with respect to the rocks that compose the peak.

The structure on Renie Peak offers the best evidence found in the area indicating differential movement between the blocks. This motion was northwest and southeast, which is in general parallel with the regional structure, and at right angles to the major thrust direction. The rocks on Renie Peak are entirely of Devonian age and have essentially a vertical attitude. Two of the regional thrust faults that cross Overlook Peak either converge or cross the gap just east of Renie Peak between Renie and Static peaks. A large major drag fold that involves all of the Palliser formation is present on the slope just southwest of Renie Peak. Development of this type of fold indicated northwest motion for the Static Peak block and southeast motion for the Renie Peak block.

The structure of the ridge on which Dessa Dawn Peak is located is relatively simple. The Mississippian-Devonian contact lies along the bottom of South Gap Canyon and lies in the relatively low South Gap between Overlook and Dessa Dawn peaks. The entire ridge is composed of Mississippian rocks. The sediments dip southwest at varying angles, the average of which is more than 45°, and the structure steepens toward Irene Creek Valley. Triassic rocks crop out well down on the west side of the ridge. A single thrust fault crosses the ridge, more or less parallel with the regional structure, and cuts through the type section of the Dessa Dawn formation repeating part of the section. The lower part of member 4 of the Dessa Dawn formation is overthrust onto the top of member 5 on the southwest wall of South Gap Canyon, where the type section was measured. The drag folds above the fault plane indicate that the upthrown thrust block had a strong southwest component in its thrust. This is the same type of differential motion that is developed east of Renie Peak, and in the same direction.

It is apparent from a study of the areal map that a regional fault crosses the regional structures in Wapiti River Valley. The present river has developed its valley along the fault plane. Because of the lake and the alluvial cover, the fault is not exposed. Its presence can be determined only by projection of the formations across the valley. Since the formations dip west, it is apparent that the area north of Wapiti River represents the upthrown block, and that if differential adjustment took place, the northern block moved southwest. Differential adjustment to thrusts in which the easternmost block of each thrust block moved northwest would inevitably result in cross structures in which the southeastern block would be offset toward the northeast.

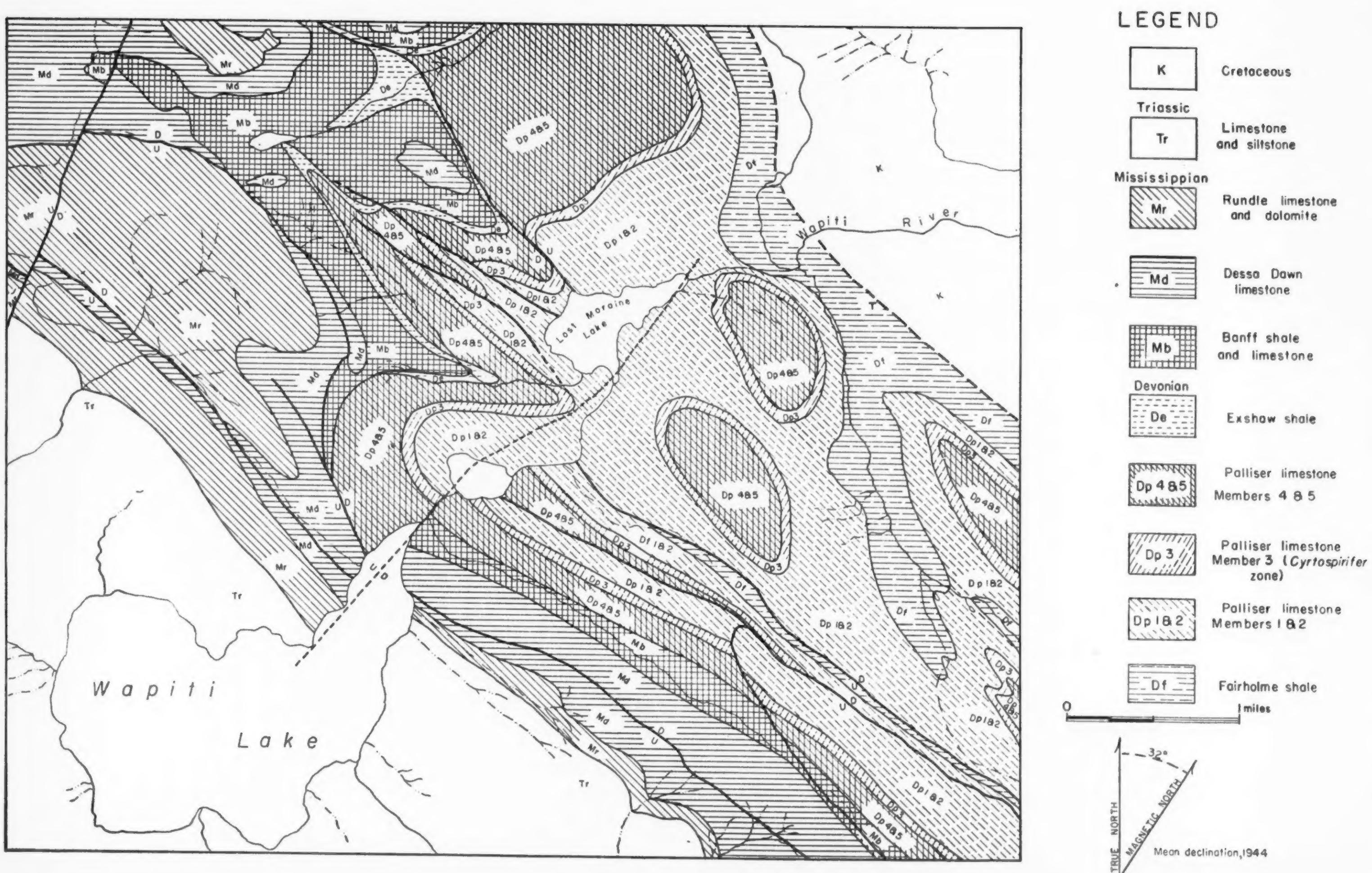
The structures north of Wapiti River are more complex. The northwest-southeast trend of the ridges is not well developed north of Wapiti River Valley because glaciers in the head of the Frozen Lake Creek drainage system excavated valleys directly across this normal topographic trend. The western ridge, on which Pamela and Twin Peaks are located, follow normal northwest-southeast topographic and structural trends, while Cave Ridge, the ridge on which Wapiti Peak is located, and the ridge on which Lee Peak is located trend across the structure.

The structure of the Rigby Peak area, which includes the flat-topped spur that projects eastward along the north side of Wapiti River to the Paleozoic boundary fault, exhibits structural features somewhat different from any found south of Wapiti River. Three faults, with accompanying drag folds, complicate the structure of the Rigby Peak area. In all three cases the fault plane dips northeast instead of southwest. The easternmost fault is a reverse fault with the eastern block upthrown. The other two are both normal faults with the eastern block downthrown (Fig. 8, section *CD*). These faults were formed in response to compression from the west by the Pamela Peak thrust block, and resistance to compression on the eastern side by the abrupt, imposing anticlinal structure in the Cretaceous rocks immediately east of the Paleozoic boundary fault.

The lower end of North Gap Canyon is located very near the axis of an abrupt, slightly overturned syncline. This syncline and an anticline adjacent on the west, at the base of Pamela Peak, were formed in response to compression caused by the Pamela Peak thrust. Drag folds associated with this thrust are well exposed along the walls of the west side of North Gap Canyon. Along the lower walls of the east side of North Gap Canyon the beds are overturned.

The structure of the Pamela Peak area is similar to that developed in the area south of Wapiti River. Structurally, Pamela Peak consists of a single thrust block, complicated by two minor associated thrust faults. The major thrust can be traced along the southeast face of Pamela Peak, along the southwest wall of North Gap Canyon, finally crossing the ridge between Twin Peaks (Figs. 9a and 9b).

A small branch fault, apparently associated with the major thrust, cuts upward across the lower slope of Pamela Peak, and is absorbed in the soft, shaly



TEXT FIGURE 10, Areal geology, Wapiti Lake area.

beds of member 4 of the Dessa Dawn formation without reaching the surface of the peak. On the west side of the peak it is represented by a local anticlinal structure (Fig. 8, section *CD*).

A smaller thrust repeats part of the Rundle section low on the western slope of Pamela Peak. Triassic beds crop out lower on the southwest slope and are generally grass-covered.

Hard, resistant Palliser limestone is upthrown against the Exshaw shale on the east side of the easternmost Rigby Peak fault where it crosses Frozen Lake Creek. A small waterfall and canyon have been formed where the creek falls over the resistant Palliser limestone. This same fault passes through the gap between Cave Ridge and Wapiti Peak.

The structure of Wapiti Gap between Wapiti and Twin Peaks is anticlinal, exposing the upper part of the Banff formation in the gap area.

A second cross-structure fault crosses the area in the creek valley and low pass immediately north of Wapiti and Twin Peaks. As in the Wapiti River Valley, the northwesternmost block is upthrown and, if horizontal motion is present, the southeastern block has moved northeast.

RESERVOIR ROCKS

One of the purposes in a detailed stratigraphic study is to determine, if possible, the potential petroleum-producing rocks within the section. Stratigraphic details concerned with distribution of rocks, direction toward shorelines, facies changes within rocks are all important in the search for oil.

Some of the rocks of the Wapiti Lake area are good potential petroleum reservoirs. Two zones within the Devonian rocks offer possibilities for petroleum accumulation. The coral-reef beds, well developed near the top of member 3 in the Palliser formation, are porous enough, on the surface at least, to be excellent reservoir rocks. The limestone beds in the Palliser formation immediately below the Mississippian contact should be examined closely in any drilling operation. Black, bituminous shales of the basal Mississippian immediately overlie these pre-Mississippian weathered limestone beds. Black shales again overlie the Devonian limestones where the Exshaw formation is present, but the erosion interval is greater where Mississippian rocks rest directly on the Devonian.

The bituminous sand lenses just above the Mississippian contact, although thin in the Wapiti Lake area, may thicken, particularly northwest in the direction of the source area. These sands are deposited in black, bituminous shales.

The Banff formation has essentially no rocks that might be considered favorable for petroleum accumulation.

The Dessa Dawn formation contains massive beds of fragmentary, crinoidal limestone not unlike the fragmental materials found in crinoid reefs in New Mexico. On surface exposures these beds weather to form very porous rock. Member 3 of the Dessa Dawn formation is particularly rich in these fragmental, crinoidal limestone beds.

The Rundle formation offers exceptional opportunities for petroleum accumulation throughout the section in the Wapiti Lake area. It rests on an erosion surface of marked relief, with many possibilities for the formation of stratigraphic traps. It contains remarkably soft, brown, sandy, porous to cavernous dolomites throughout. The lower massive beds north of Wapiti River are the type that might be expected to contain oil. There is essentially no part of the Rundle formation in this area that should be overlooked as a potential oil-bearing bed.

Beds of highly cavernous chert reworked from the underlying Rundle formation and ranging from 3 feet to 15 feet in thickness are found in the base of the Triassic. They are overlain by black marine shales.

REFERENCES CITED

ALLAN, JOHN A. (1914), "Rocky Mountain Section between Banff, Alta., and Golden, B. C., along the Canadian Pacific Railway," *Canada Geol. Survey Summ. Rept.*, Session Paper 26, pp. 165–76.

———, WARREN, P. S., AND RUTHERFORD, R. L. (1932), "A Preliminary Study of the Eastern Ranges of the Rocky Mountains in Jasper Park, Alberta," *Trans. Royal Soc. Canada* (3rd Ser.), Vol. 26, Sec. 4, pp. 225–49; 2 figs., 2 pls.

BURLING, L. D. (1916), "Notes on the Stratigraphy of the Rocky Mountains, Alberta and British Columbia," *Canada Geol. Survey Summ. Rept. 1915*, pp. 97–100.

BEACH, H. H. (1943), "Moose Mountain and Morley Map-Areas, Alberta," *Canada Geol. Survey Mem. 236*, pp. 1–74, maps.

CAMERON, ALAN E. (1922), "Hay and Buffalo Rivers, Great Slave Lake, and Adjacent Country," *Canada Dept. Mines Summ. Rept. 1921*, Pt. B, pp. 1–44, map.

——— (1936) "The South Nahanni River, Northwest Territories," *Canada Geog. Jour.*, Vol. 13, pp. 37–45.

———, AND WARREN, P. S. (1938), "Geology of the South Nahanni River, Northwest Territories," *Canada Field Naturalist*, Vol. 52, No. 2, pp. 15–18; 2 figs.

CAMSELL, C., AND MALCOLM, W. (1919), "The Mackenzie River Basin," *Canada Geol. Survey Mem. 108*, pp. 1–54; 14 pls., 1 fig., map.

COOPER, G. A., ET AL. (1942), "Correlations of the Devonian Sedimentary Formations of North America," *Bull. Geol. Soc. America*, Vol. 53, pp. 1729–94; 1 pl., 1 fig.

DAWSON, G. M. (1887), "Notes to Accompany a Geological Map of the Northern Portion of the Dominion of Canada East of the Rocky Mountains," *Geol. and Nat. Hist. Survey Canada Ann. Rept. 2*, pp. 1–62.

——— (1888), "Report of an Exploration in the Yukon District, Northwest Territory, and Adjacent Portion of British Columbia," *Canada Geol. Survey Ann. Rept. 3*, Pt. B, pp. 1–183.

DEISS, C. F. (1933), "Paleozoic Formations of Northwestern Montana," *Montana Bur. Mines and Geol. Mem. 6*. 51 pp., 3 pls.

DOWLING, D. B. (1907), "Report on the Cascade Coal Basin, Alberta," *Canada Geol. Survey Sessions Paper 26B*. 37 pp., maps.

HAGE, C. O. (1945), "Geological Reconnaissance along Lower Liard River, Northwest Territories, Yukon, and British Columbia," *Canada Geol. Survey Paper 45-22*. 33 pp., map.

HUME, G. S. (1921), "Great Slave Lake Area," *Canada Geol. Survey Summ. Rept. 1920*, Pt. B., pp. 30–36.

——— (1922), "North Nahanni and Root Rivers Area and Caribou Island, Mackenzie River District," *ibid., Summ. Rept. 1921*, Pt. B, pp. 67–78; 2 pls.

——— (1922a), "Norman Oil Fields, Mackenzie River Area," *Canada Mining Jour.*, Vol. 43, No. 48, pp. 816–7.

——— (1923), "A Kinderhook Fauna from the Liard River, N. W. T., Canada," *Amer. Jour. Sci.* (5th Ser.), Vol. 6, pp. 48–52; 1 fig. (map).

——— (1923a), "Geology of the Norman Oil Fields and a Reconnaissance of a Part of the Liard River," *Canada Geol. Survey Summ Rept. 1922*, Pt. B., pp. 47–64; 2 pls., map.

———, AND LINK, T. A. (1945), "Canol Geological Investigations in the Mackenzie River Area, Northwest Territories and Yukon," *Canada Geol. Survey Paper 45-16*. 87 pp., 3 pls., 21 figs., maps.

KEELE, JOSEPH (1910), "A Reconnaissance across the Mackenzie Mountains on the Pelly, Ross, and Gravel Rivers, Yukon and Northwest Territories," *Canada Geol. Survey*. 54 pp., map.

KINDLE, EDWARD D. (1944), "Geological Reconnaissance along Fort Nelson, Liard, and Beaver Rivers, Northeastern British Columbia and Southeastern Yukon," *Canada Geol. Survey Paper 44-16*. 19 pp., 1 pl., map.

——— (1945), "Geological Reconnaissance along the Canol Road from Teslin River to MacMillan Pass, Yukon," *ibid., Paper 45-21.* 26 pp., 1 pl., map.

KINDLE, E. M. (1914), "The Silurian and Devonian Section of Western Manitoba," *Canada Geol. Survey Summ. Rept. 1912*, pp. 247–61.

——— (1916), "Notes on the Devonian Faunas of the Mackenzie River Valley," *Amer. Jour. Sci.* (4th Ser.), Vol. 42, pp. 246–48.

——— (1924), "Standard Paleozoic Section of the Rocky Mountains near Banff, Alberta," *Pan-Amer. Geologist*, Vol. 42, pp. 113–24.

——— (1929), "The Succession of Fossil Faunas in the Eastern Part of Jasper Park," *Amer. Jour. Sci.* (5th Ser.), Vol. 18, pp. 177–92.

———, AND BOSWORTH, T. O. (1921), "Oil-Bearing Rocks of the Lower Mackenzie River Valley," *Canada Geol. Survey Summ. Rept. 1920*, Pt. B, pp. 37–63; 2 figs., 3 pls., map.

LAUDON, L. R. (1948), "Osage-Meramec Contact," *Jour. Geol.*, Vol. 56, No. 4, pp. 288–302.

———, AND CHRONIC, B. J., JR. (1947), "Mississippian Rocks of Meramec Age Along Alcan Highway," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 31, No. 9, pp. 1608–18; 3 figs.

——— (1949), "Paleozoic Stratigraphy along Alaska Highway in Northeastern British Columbia," *ibid.*, Vol. 33, No. 2, pp. 189–222; 12 figs.

MCCONNELL, R. G. (1887), "Report on the Geologic Structure of a Portion of the Rocky Mountains," *Geol. and Nat. Hist. Survey Canada Ann. Rept. 1886*, Pt. D. 41 pp.

——— (1891), "Report on an Exploration in the Yukon and Mackenzie Basins," *ibid., Ann. Rept.* (New Ser.), Vol. 4 (1888–1889), Rept. D, pp. 1–145.

PERRY, EUGENE S. (1945), "Distribution of Sedimentary Rocks in Montana and the Northwestern Great Plains," *Montana Bur. Mines and Geol. Misc. Contrib. 8.* 10 pp., charts.

RAYMOND, P. E. (1930), "The Paleozoic Formations in Jasper Park, Alberta," *Amer. Jour. Sci.* (5th Ser.), Vol. 20, pp. 289–300.

SHIMER, H. W. (1913), "Spiriferoids of the Lake Minnewanka Section, Alberta," *Bull. Geol. Soc. America*, Vol. 24, pp. 233–240.

——— (1926), "Upper Paleozoic Faunas of the Lake Minnewanka Section, near Banff, Alberta," *Canada Geol. Survey Bull. 42*, pp. 1–84; 1 fig., 8 pls.

SLOSS, L. L., AND LAIRD, W. M. (1945), "Mississippian and Devonian Stratigraphy of Northwestern Montana," *U. S. Geol. Survey Prelim. Chart 15*, Oil and Gas Inves. Ser.

WARREN, P. S. (1927), "Banff Area, Alberta," *Canada Geol. Suvey Mem. 153.* 94 pp., 7 pls., map.

——— (1937), "Age of the Exshaw Shale in the Canadian Rockies," *Amer. Jour. Sci.* (5th Ser.), Vol. 33, No. 198, pp. 454–57.

WHITTAKER, EDWARD J. (1922), "Mackenzie River District between Great Slave Lake and Simpson," *Canada Geol. Survey Summ. Rept. 1921*, Pt. B, pp. 45–57.

——— (1923), "Mackenzie River District between Providence and Simpson, Northwest Territories," *ibid., Summ. Rept. 1922*, Pt. B, pp. 88–100; 2 figs., 2 pls.

WILLIAMS, M. Y. (1922), "Exploration East of the Mackenzie River between Simpson and Wrigley," *ibid., Summ. Rept. 1921*, Pt. B, pp. 56–66; map.

——— (1923), "Reconnaissance across Northeastern British Columbia and the Geology of the Northern Extension of Franklin Mountains, Northwest Territories," *ibid., Summ. Rept. 1922*, Pt. B, pp. 65–87.

——— (1944), "Geological Reconnaissance along Alaskan Highway from Fort Nelson, British Columbia to Watson Lake, Yukon," *ibid., Paper 44-28.* 33 pp., 1 pl., map.

———, AND BOCOCK, J. B. (1932), "Stratigraphy and Paleontology of the Peace River Valley of British Columbia," *Trans. Royal Soc. Canada* (3d Ser.), Vol. 26, Sec. 4, pp. 197–224.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 33, NO. 9 (SEPTEMBER, 1949), PP. 1553-1578, 8 FIGS.

GEOLOGY AND PETROLEUM EXPLORATION IN MAGALLANES PROVINCE, CHILE[1]

C. R. THOMAS[2]
Punta Arenas, Chile

ABSTRACT

Previous to 1917 eight tests for oil or gas were made in this territory. In 1925 the search for oil was taken over by the Chilean Government and up to 1942 the Departamento de Minas y Petróleo made 7 tests which, though not producing commercially, found good showings of oil and gas in two different zones and in three different localities. In 1942 the search for oil was taken over by the Corporación de Fomento de la Producción and since that time one oil field has been found, partly developed, and another wildcat well, San Sebastián No. 1, has found 19 meters of oil-saturated sand in the same zone.

The oldest sediments studied for oil production are probably Jurassic. This series is thought to be the equivalent of the Serie Porfírica of Argentina. About 6,600 meters of Upper Cretaceous and 5,000 meters of Tertiary rocks, all of which are marine sediments, have been measured. An unmeasured series, approximately 2,000 meters thick, of non-marine Tertiary deposits lies above the marine sediments. Much of the territory is covered by a blanket of fluvio-glacial deposits of unknown thickness.

The principal sedimentary feature is the Magallanes basin the west side of which is just east of the Cordillera front and the east side of which is unknown, but drilling to date indicates it to be at or east of the Manantiales field as 6,000–8,000 meters of rocks have been cut out in that area.

Four major and an uncounted number of minor unconformities have been recognized in this territory.

In general the rocks nearest the Cordillera are crushed and crumpled, and somewhat farther removed they are steeply folded and still farther eastward the folds are gentler and broader. Strike faults have also been developed.

In view of the great thickness of marine sediments and the fact that one oil field and indications of another already exist on the east flank, the possibilities of finding additional commercial oil appear good.

BRIEF HISTORY OF PREVIOUS WORK

Most of the early geological reports on this territory are not available at this time but Darwin, Philippi, Weddel, Quensel, Halle, Suess, Nordenskjold, Daly, Felsh, and others have contributed. More recent work by Feruglio and Windhausen, though dealing primarily with Argentina, also throws considerable light on the geology of this region.

The earliest work on petroleum geology available in this office is by Guido Bonarelli.[3] This was followed by the reports of the Keidel-Hemmer[4] and Decat-

[1] Read before the Association at St. Louis, by Clark Millison, March 17, 1949. Manuscript received, March 29, 1949. Published by permission of the Corporación de Fomento de la Producción, Chile.

[2] Head of the exploration department in Magallanes Province for the Corporación de Fomento de la Producción. Most of the geological data in this report were obtained from reports of the work done by geologists and geophysicists of the United Engineering Corporation and the United Geophysical Company. Valuable help and assistance were given by the engineers and officials of the Corporación de Fomento.

[3] Guido Bonarelli, *Informe Geológico sobre Exploraciones Petrolíferas en Magallanes* (1917).

[4] I. Keidel y A. Hemmer, "Informe preliminar sobre las investigaciones en la región petrolífera de Magallanes en los meses de verano de 1928–1929," *Boletín del Departamento de Minas y Petróleo Ministerio de Fomento* (Chile, Agosto, 1931), pp. 44–55.

Pomeyrol[5] reports in 1929 and by Hemmer[6] in 1935. Many unpublished reports made by geologists of the United Geophysical Company and the United Engineering Corporation are also in the files.

Previous to 1917 eight tests for oil and gas were drilled in this region. None of these appears to have had any important results. In 1917 Bonarelli[7] recommended a location along the Leña Dura River. The results from this test were similar to those of its predecessors.

From 1917 to 1930 no additional tests appear to have been drilled.

In 1925 the Government of Chile assumed possession of the oil rights of the country and in 1928 the Departamento de Minas y Petróleo sent two geological commissions into the territory to make geological investigations and to carry on drilling explorations for the purpose of finding oil. These were known as the Keidel-Hemmer and the Decat-Pomeyrol commissions, and as a result of their studies locations were made and tests were drilled. By 1931 Hemmer was in complete charge of the operations and under his directions 7 tests were drilled between 1930 and 1942.

In 1942 the Corporación de Fomento de la Producción was given the responsibility of exploring for oil in this province. Luciano Claude was named as head of the operation with Osvaldo Wenzel as chief geologist for Fomento. The local operations were carried on with Eduardo Simián as chief engineer, Jorge Pacheco, next in command, and assisted by Bernardo Grossling, Carlos Mordojovich, and Hernán Briceño. The geological exploration was contracted to the United Geophysical Company, with Glen M. Ruby in general charge, L. K. Morris in charge of the geophysical work, and J. S. Hollister in charge of geological exploration. L. K. Morris and John Smith were chiefs of the geophysical parties and E. S. Shaw, W. T. Thoms, Harve Loomis, Karl L. Walter, and C. L. Mohr were among the geologists assisting in the enterprise.

In 1945 the exploration activities were subdivided, the United Engineering Corporation doing the geological work and directing the balance of the enterprise and the United Geophysical Company doing the geophysical work under separate contract. In 1947 the United Engineering Corporation's contract expired and since June of that year the exploration activities have been directed by personnel employed directly by the Corporación de Fomento. The United Geophysical Company operates one seismic party with L. K. Morris in charge and R. K. Gilbert as party chief. One gravity party and one seismic party are being operated by the Corporación de Fomento.

In 1945 two tests, both on seismic data, were started: one with rotary tools, the other with a spudder. One, Manantiales No. 1, was successful; the other, Mina Rica No. 1, was a failure. Since that time four additional seismic tests have

[5] Jules Decat y R. Pomeyrol, "Informe Geológico sobre las posibilidades petrolíferas de la Región Magallanes," *ibid.* (Septiembre, 1931), pp. 69–77.

[6] Augusto Hemmer, "Geología de los Terrenos Petrolíferos de Magallenas y las Exploraciones Realizadas," *Instituto de Ingenieros de Minas de Chile* (1935).

[7] Guido Bonarelli, *op. cit.*, p. 83.

been made, and one well started, but not completed, on a surface anticline.

In all, six wildcats have been completed on seismic structures, one of which produced oil or gas, and the only test to date on a surface anticline was shut down before reaching its objective.

To date, January 15, 1949, the Manantiales field has 8 oil wells, 4 gas wells, 3 wells with high gas-oil ratios, and 1 drilling well, 2 dry holes. The San Sebastián wildcat had 19 meters of saturated oil sand which produced very little fluid. The second test acted similarly, and since this appeared to be an area of low permeability, that area has been temporarily abandoned. A pipe line from the Manantiales field to Puerto Percy on Bahía Gente Grande is being surveyed and contract has been made.

GEOGRAPHY

Three world known geographical features occur in this province: the Straits of Magellan, Cape Horn, and Tierra del Fuego.

The topography of Magallanes Province is varied and may be divided into three zones.

That part bordering the Pacific Ocean is known as the canal zone and consists of an uncounted number of land masses: islands, peninsulas, capes, points, and promontories connected by an innumerable number of waterways; canals, estuaries, sounds, lakes, and bays. The land surfaces rise abruptly from sea-level and consist mostly of igneous (granitoid) and metamorphic rocks. This zone is rough, rugged, and mountainous, with timber near the water's edge, but with many glaciers in the mountains, some of which reach down to sea-level.

The eastern zone is the southern extension of the Patagonian Pampa and is a low, flat, bald prairie consistently covered with bunch grass with a few bushes and no trees. This is the grazing district of the province.

Between these two zones lies another zone, mostly covered with dense timber, locally, but incorrectly, called roble. The eastern ranges of hills are rounded and covered with glacial débris, and for the most part, though well timbered, they have extensive turbal (peat bog)-covered areas. The western hills are cuestas and hog-backs, and have more timber, and less turbal. The rocks in this area are mostly the Cretaceous sedimentaries.

One prominent feature in Magallanes Province is the fact that extensive waterways exist over much of the territory and lakes of all sizes may be found well scattered throughout the area. The Straits of Magellan enter from the east into the prairie province and the western exit is in the canal zone.

The principal industry is sheep-raising. The prairie province is entirely devoted to raising sheep and both wool and mutton are exported in considerable quantity. Because of its very high quality some of the wool from here commands top prices in the world market. Huge fortunes have been made from this business within the last 60 years. Years ago some placer gold had been found on Tierra del Fuego, but recent attempts to modernize this business have not proved

profitable. A number of coal mines exist in the territory, but the coal produced is largely for local consumption as the grade is not quite good enough for export. The business of supplying wood for fuel employs a number of people, but the wood secured is for local consumption. Some sawn wood is exported, but the quantity is negligible. A few garden spots, and a very few oat fields have been plowed, but, except for meats, practically all foodstuffs are imported.

There are three cities in the province. Punta Arenas, with a population of about 35,000, is the capital and the largest. It is the principal port of the region and most of the shipping is handled here. Natales, the second largest, with a population of about 10,000, is also a seaport. Porvenir, the smallest, with a population of about 5,000, though a seaport, can handle only the smaller vessels.

A few hard-surfaced, all-weather roads cross the mainland. The most important extends from the border, close to the east entrance of the Straits of Magellan, through Punta Arenas to Fort Bulnes. Similar roads go through Natales and north to Estancia Guido near the north end of the province, and from Punta Arenas to Senos (Sounds) Skyring and Otway.

Many trails connect the various estancias both on the mainland and on Tierra del Fuego, but auto travel on these during the winter is not for fun, pleasure, or amusement. In summer, and under the very best conditions, an average speed of one kilometer per minute is regarded as a very good record.

Bus lines operate over most of the highways, and mail cars over many of the poorer trails. Of recent years the LAN (National Air Lines) has inaugurated air service between all the towns, to some estancias, and to the Manantiales oil field. Trips, at least once per week, are regularly made to Santiago. Sea-going vessels put into harbor every 1 to 2 weeks.

All the cities have telephone service, as have most of the estancias, but the only direct communication between Tierra del Fuego and the mainland is by the heliograph of the Explotadora and the radio of the Corporación de Fomento.

The climate, while not severe, definitely is not good. The average temperature is 6.9°C., and the lowest during the winter is -13°C., but seldom is lower than -10°C. However, any judgment of the climate based on these figures will result in an erroneous conception. Very few warm days (shirt-sleeve type) occur during the summer, and very few calm days occur during the year. The most noticeable feature regarding the climate is the wind. While winds of 100 kilometers per hour are not frequent, practically any wind less than 40 kilometers per hour is regarded as a zephyr. Though the cloudy days outnumber the sunny days by a comfortable margin, the prevalence of the wind, rather than the lack of sun, is the most important factor in keeping this a grazing, rather than a farming territory.

The aboriginal inhabitants of this region were Indians of a rather low mentality, but of a very high degree of toughness. They wore no clothes, and many of them lived in holes dug into the ground. They lived on sea food and guanacos, a cousin to the llama. Sometime after the discovery of this territory, various mis-

sionaries appeared bringing clothes for the Indians. Some of these clothes were infected. The missionaries clothed the Indians and many died from the infectious diseases. The change in manner of living resulted in many more dying from tuberculosis and pneumonia. On the whole, many were eliminated in this manner. In later years the discovery that sheep-raising was profitable resulted in the Indians finding out that sheep were easier to catch than guanacos and fish. Since this practice interfered with the profit, the sheep-raisers eliminated the bulk of those overlooked by the missionaries. As a result very few people of Indian blood exist in the province at this date. At the moment it is difficult to determine if people of Spanish or Yugo-Slav descent predominate. There are few people of British descent, with a scattering of people from various European countries.

GEOLOGY

Some of the older reports mention Paleozoic rocks as being observed in the canal zone. Since most of the more recent surveys have been looking for oil, little attention has been paid to this zone and these reports have been neither verified nor disproved.

STRATIGRAPHY

The batholic intrusion of granitoid rocks in the canal zone has formed a zone of metamorphic rocks, both gneisses and schists, between it and the oldest sediments described in this report.

SERIE TOBÍFERA

The oldest rocks studied in recent investigations are known as the Serie Tobífera, and except for the samples from Manantiales No. 2, very little time has been devoted to this series. While rocks of this type have been reported by earlier investigators the only surface exposure visited in recent surveys is along the north end of the canal Gajardo (which connects Seno Skyring with the Straits of Magellan).[7a]

About 1,000 meters of this formation have been penetrated in Manantiales No. 2, in which locality it consists primarily of volcanic ash and alteration products of same. The basal part had a great quantity of mica schist and the drilling time was much greater than average, but since a considerable quantity of similar material had been penetrated farther up the hole, though the conclusion was reached that this schist was a part of the basement rocks, the data were inconclusive.

At the surface the rocks were metamorphosed, but though little of the exposed section was studied, and no measurements were made, it is definitely the same type of material. From the data collected it is impossible to make an estimate of its thickness, but an approximation of 3,000 meters should not be greater than its actual thickness.

[7a] Wide exposures of the Serie Tobífera have been observed along the south shore of Seno Almirantasgo.

In Manantiales No. 2 this formation is a sedimentary volcanic ash, partly weathered to kaolinite, with some gray shale, a few streaks of siliceous shale, many quartz and calcite crystals, scarce feldspar crystals, and near the top a 30-meter section of coarse, rounded, well cemented quartz sand.

No direct evidence is available regarding the age of the Serie Tobífera but Glen M. Ruby and A. L. Gaitán, both of whom are familiar with the Serie Porfírica of Argentina, consider them to be approximate equivalents. The age of the Serie Porfírica has been considered by some as Upper Jurassic.

SPRINGHILL SAND

No surface exposure of the Springhill sand has yet been discovered.

Lying unconformably above the Serie Tobífera in the Manantiales field is a sand body ranging from 10 to 30 meters in thickness. The grain size ranges from medium to coarse, and where cemented the cement varies from hard to soft kaolinite. The most noticeable characteristic is the fact that many of the quartz grains are crystalline and still maintain most of their sharp edges. Some shale and coal streaks are found within the formation.

The age of this formation is unknown. It is younger than the Serie Tobífera (Upper Jurassic?) and older than the Turonian of the Upper Cretaceous.

INOCERAMUS SHALES

Lying unconformably above the Serie Tobífera is a great thickness of hard, dark gray, siliceous shales containing *Inocerami* and a teredo-like fossil? locally called "Holy Joe." Hemmer[8] referred to these shales as "Estratos con Inocerami." Decat-Pomeyrol[9] named them "Serie Limite" meaning the limit of their investigations. Hollister[10] referred to them in general as "Pre-Remarcable," and had measured, named, and described a number of formations in various localities, all of which he referred to this group. His Cabo Froward, Nassau, Bourand, Barcarcel, Indio, Pilar, *et cetera* are of this category. He placed the total thickness at 4,905 meters, but since this was the addition of various formations from various localities it is possible that some overlapping of measurements took place. More recent investigations have thrown no additional light on the total thickness of this series, but 1,500 meters, with no base in sight have been measured near Estancia Cerro Castillo, and an estimate of their thickness would place it at no less than 3,000 meters.

In the Manantiales field about 750 meters of shales containing *Inoceramus* prisms have been regarded as the equivalent of the lower part of this group. This group has been well subdivided on lithologic and foraminiferal evidence in that locality, but, to date, no outcrop foraminifera have been found in the *Inoceramus* shales and no exact correlation has been made with surface exposures.

[8] *Op. cit.*, p. 147.

[9] *Op. cit.*, p. 70.

[10] J. S. Hollister, *Report on United Geophysical Company 1943–1944*, p. 22. (Not published.)

ROSA CONGLOMERATIC SERIES

The use of the term Rosa for this formation is not in line with the best geologic practice, because at Rosa Point, the type locality, the lower part of the formation is cut off by a fault and much of the formation is not exposed. At Rosa Point 35 meters of very fine-grained, hard, siliceous, well cemented sandstone, overlain by 75 meters of coarse-grained sandstone, above which are 90 meters of medium-grained sandstone, are described as the Rosa Conglomeratic series. Westward this sandstone grades first into sandstone and conglomerate, and farther west at Point Adelaide a basal 20 meters of dark-colored conglomerate, overlain by 225 meters of fine-grained sandstone with interbedded shale streaks, above which are 125 meters of conglomerate, are considered to be the same formation.

Hollister[11] has measured 200 meters at Remarcable Point, and referred to it as the "Remarcable conglomerate." Hemmer[12] took the type locality at Valdés Point on Dawson Island, referred to it as "Valdés," and estimated 500 meters as the thickness of the series.

In the Natales area the eastern exposures of this series are primarily coarse-grained sandstones, but as the formation is traced toward the west, toward the mountains, the grains increase in diameter and many boulders as large as 1 meter in diameter are observed.

This formation varies from 200 to 500 meters in thickness.

Its age is Upper Cretaceous.

Good showings of oil and gas were encountered in this formation in the R-4 well on Prat Point. It should make a good reservoir rock.

FUENTES SHALE

The type locality for this shale is in Fuentes Bay on Seno Skyring. At that place 1,220 meters have been measured. It is hard, dark gray, siliceous shale with thin limestone and sandstone beds. Its thickness varies greatly, ranging from 360 meters in Bahía Herradura (the small bay within Bahía Boníta) to 2,800 meters near Fort Bulnes (at Santa Ana Point on Península Brunswick).

Its age is Upper Cretaceous.

ROCALLOSA SANDSTONE

Unconformably above the Fuentes shale is the Rocallosa sandstone. The type locality is at Rocallosa Point on Seno Skyring. At this locality 340 meters of fine- to medium-grained, slightly shaly, glauconitic sandstone are exposed. The basal 25–30 meters are coarser-grained. Medium-sized (5–30 centimeters) spherical limestone concretions are sparsely scattered throughout the formation, but are found more commonly near the base.

This formation, though not measured, is thought to be much thicker on

[11] *Op. cit.*, p. 14.

[12] *Op. cit.*, p. 147.

Mount Tarn. It is conglomeratic at its western exposure on the north side of Seno Skyring.

This sandstone is exposed in many localities on Península Brunswick and odors of oil have been noticed in many of these localities. Though not very porous it offers possibilities as reservoir rock.

The age of this sandstone is Upper Cretaceous.

CHORRILLO CHICO SILTSTONE

The type locality for the Chorrillo Chico siltstone is along the east side of Rocallosa Point, at which locality the Chorrillo Chico cuts across the formation. It is a hard, shaly, glauconitic siltstone with thin beds of limestone and limestone concretions. Except for the size of the grains it is lithologically similar to the Rocallosa sandstone.

Its thickness, at the type locality, is no less than 185 meters, but covered areas at that place extend 80 meters above and 60 meters below the exposed part.

Its age is thought to be Upper Cretaceous, and tentatively it is considered as being the youngest Cretaceous rock in this province. This formation was originally thought to belong to the overlying shale series, but recent foraminiferal and lithologic studies indicate that its relationship is closer to the Rocallosa than to the shale above.

AGUA FRESCA SHALE

This term has been adopted instead of the term "Skyring" which was used by Hollister. This change was made for three reasons: (1) the Seno Skyring, from which the name was derived, has exposures along it of practically all the formations from the *Inoceramus* shales up; (2) the exposures of this formation along Seno Skyring are far from complete, and a good section can not be measured in that locality; (3) the term Agua Fresca was used by Decat-Pomeyrol for the same rocks, and their type locality, along the Río Agua Fresca, presents a better exposed section.

The Agua Fresca is a light-colored, readily weathered, clay shale with some layers of large limestone concretions.

Its thickness is about 2,100 meters.

This shale contains an abundant foraminiferal fauna and has been subdivided on this evidence.

Its exact age has not yet been determined, but the lower part is considered as being no older than middle Eocene.

TRES BRAZOS SANDSTONE

The type locality for the Tres Brazos sandstone is along the Tres Brazos River, but its greatest thickness has been measured on the Río Grande anticline along the south shore of Seno Otway. This formation is a medium-grained, well assorted, glauconitic sandstone with layers of large, spherical, silica-cemented,

sandstone concretions, and with some small, fossiliferous limestone concretions.

Its thickness varies from 1,500 meters on the Río Grande anticline to 160 meters in the Mina Rica well and it is absent in the Tres Puentes area (not far northwest of Punta Arenas).

The fact that this sandstone disappears toward the east, and that its eastern edge achieves no great depth before disappearing leaves the prospects for its making a good reservoir rock rather dim, even though it has marine shales above and below.

It also is found in the wells at Manantiales, San Sebastián, and Espora, in which localities it is a very fine-grained, very glauconitic, shaly sandstone.

Its age may be upper Eocene.

LEÑA DURA SHALE

The type locality for the Leña Dura shale is along the Leña Dura River. It is a hard, firm, gray shale with layers of large (up to 1 meter and larger) spheroidal, fossiliferous, limestone concretions, and contains fairly abundant foraminifera.

On the continent its thickness is fairly constant, ranging from 300 to 330 meters, but along the south shore of Useless Bay on Tierra del Fuego it appears to be much thicker, and some shales in the San Sebastián wildcat appear to belong to this formation.

Its age is possibly upper Eocene.

LORETO SANDSTONE

The type section of the Loreto sandstone is in the vicinity of the Loreto Mine but the best exposure of the lower Loreto is found along Chorrillo Lynch.

Decat-Pomeyrol[13] subdivided this formation into "Lynch" and "Formación Lignitica" and much can be said for this subdivision. Locally the terms "Marine Loreto" (Lynch) and "Coal-Bearing Loreto" (Formación Lignitica) are in current use.

The Marine Loreto is medium- to coarse-grained, poorly assorted sandstone with numerous layers of rounded sandstone concretions with many, but poorly preserved fossils. At least two oyster beds, and one *Turritella* bed have been observed. The basal few meters, in at least two localities, is almost pure glauconite. A few thin shale beds occur near the base.

Its thickness ranges from 500 to 800 meters.

The coal-bearing Loreto is similar to the marine Loreto but in addition to the coal seams it contains more shale.

Since the top of this formation has not been observed its total thickness is unknown, but 225 meters have been measured.

The age of the Loreto may be Miocene.

Additional surface work, now in progress, will change these data to an appreciable extent.

[13] *Op. cit.*, p. 70.

PALOMARES FORMATION

Resting unconformably above the Loreto is a thick series of sandstones and conglomerates called the Palomares formation. The type section is exposed in the vicinity of the Palomares hills east of the Fitzroy Canal.

The rocks vary from shales to conglomerates but the materials are primarily of volcanic origin.

The thickness of this formation is not known, but scattered data at hand indicate at least 1,500 meters.

Its age has been determined as Pliocene.

FLUVIO-GLACIAL DEPOSITS

Covering most of the possible oil-producing territory in the province is a thick mantle of reworked glacial deposits which have been formed into a great series of terraces, no doubt a delight to the physiographer, but a distinct deterrent to the geologist. These form the zone of the pampas, and the great sheep estancias of the area lie within this zone, but even the seismic waves are dampened by this layer and the geophysicists carefully avoid the higher hills.

The thickness of these deposits is not known but as much as 185 meters have been penetrated at Manantiales.

Its age is probably Quaternary.

LORETO-TRES BRAZOS CONFUSION

Though Decat-Pomeyrol[14] had the stratigraphy of this part of the section fairly well in hand, later workers, including the earlier work done by the geologists of the United Geophysical Company, confused the Loreto with the Tres Brazos. This is quite understandable inasmuch as the exposures are far from continuous and both sandstones are coal-bearing and are underlain by gray marine shales. The understanding of the situation was cleared up by Glen M. Ruby and C. L. Mohr and was definitely settled by the foraminiferal studies of H. T. Kniker.

Since some of the previous workers had extracted fossils from Tres Brazos exposures while laboring under the delusion that these were Loreto beds it becomes obvious that any conclusions based on these fossils would be misleading. Fuenzalida,[15] however, though offering two possibilities, favors the correlation of the sandstones on the flanks of the Vaquería anticline as being older than the Loreto. These are same sands in which the coal is found in Mina Elena and which have been determined by recent workers as being Tres Brazos (Fig. 1).

DISTRIBUTION OF SEDIMENTS

In general the surface exposures of the rocks form a simple pattern.

From the granitoid mass of the batholith in the canal zone, on the Pacific slope,

[14] *Op. cit.*, p. 70.

[15] Humberto Fuenzalida V, "El Magallánico de la Isla Rieco con Referencias a algunas Regiones Adyacentes," *Anales del Primer Congreso Panamericano de Ingeniería de Minas y Geología*, Tomo Segundo (Santiago de Chile, January, 1942), pp. 420–21.

CORRELATION CHART
MAGALLANES PROVINCE, CHILE

Decot - Pomeyrol *Brunswick Peninsula*	Hemmer *Magallanes Province*	Hollister *Magallanes Province*	This report *Magallanes Province*
PALOMARES	PALOMARES	PALOMARES	PALOMARES
FORMACION LIGNITA	LORETO	LORETO	LORETO
LYNCH	BOQUERON		
LENA DURA			LENA DURA
RIO GRANDE	TRES PUENTES		TRES BRAZOS
AGUA FRESCA	BOQUERON CANELOS PRAT KELP	SKYRING	AGUA FRESCA
			CHORRILLO CHICO
FORMACION CON DYKES	PRAT TARN	ROCALLOSA	ROCALLOSA
CANELOS	SANTA ANA AGUILAR	FUENTES	FUENTES
CONGLOMERADO BASAL	VALDEZ	ROSA	ROSA CONGLOMERATIC SERIES
		BONITA	
		REMARCABLE	
SERIE LIMITE	ESTRATOS CON INOCERAMI	PRE-REMARCABLE (BOURAND, NASSAU, INDIO, BARCARCEL, CABO FROWARD, PILAR, ETC.)	INOCERAMUS SHALES
	PORFIDO CUARCIFERO		SPRINGHILL SAND
			SERIE TOBIFERA

FIG. 1.—Correlation chart, Magallanes Province, Chile.

the sediments dip east and north toward Argentina. This inclination is interrupted, however, before reaching the longitude of the Springhill field, but the effects of this interruption are not shown by the areal distribution of the outcrops.

Much of the area of exposed rocks has been mapped in much greater detail than is shown on the accompanying areal geologic map of the province (Fig. 2), but these detailed areas occupy so small a fraction of the total area that the addition of the details would only confuse the picture.

The location of the exposures of the Serie Tobífera can not be considered as exact inasmuch as some of these locations were placed on the map from written descriptions, not maps, from some of the older publications.

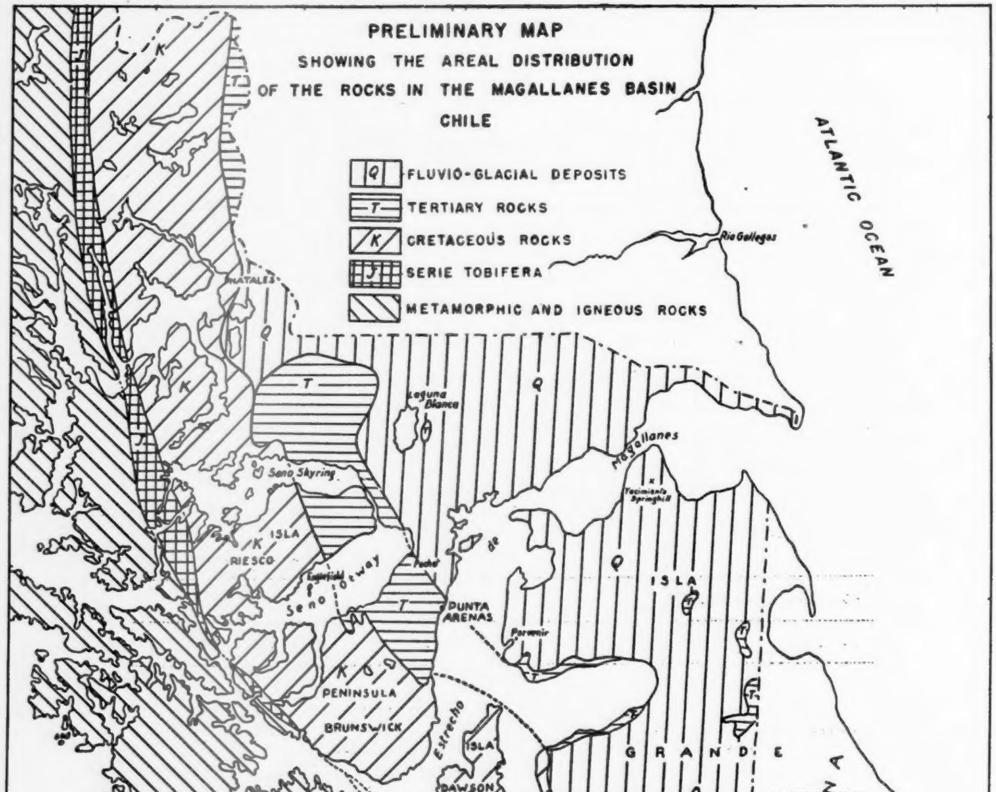


FIG. 2.—Preliminary map showing areal distribution of rocks in Magallanes Province, Chile. Scale: 1½ inches equal approximately 1,000 kilometers.

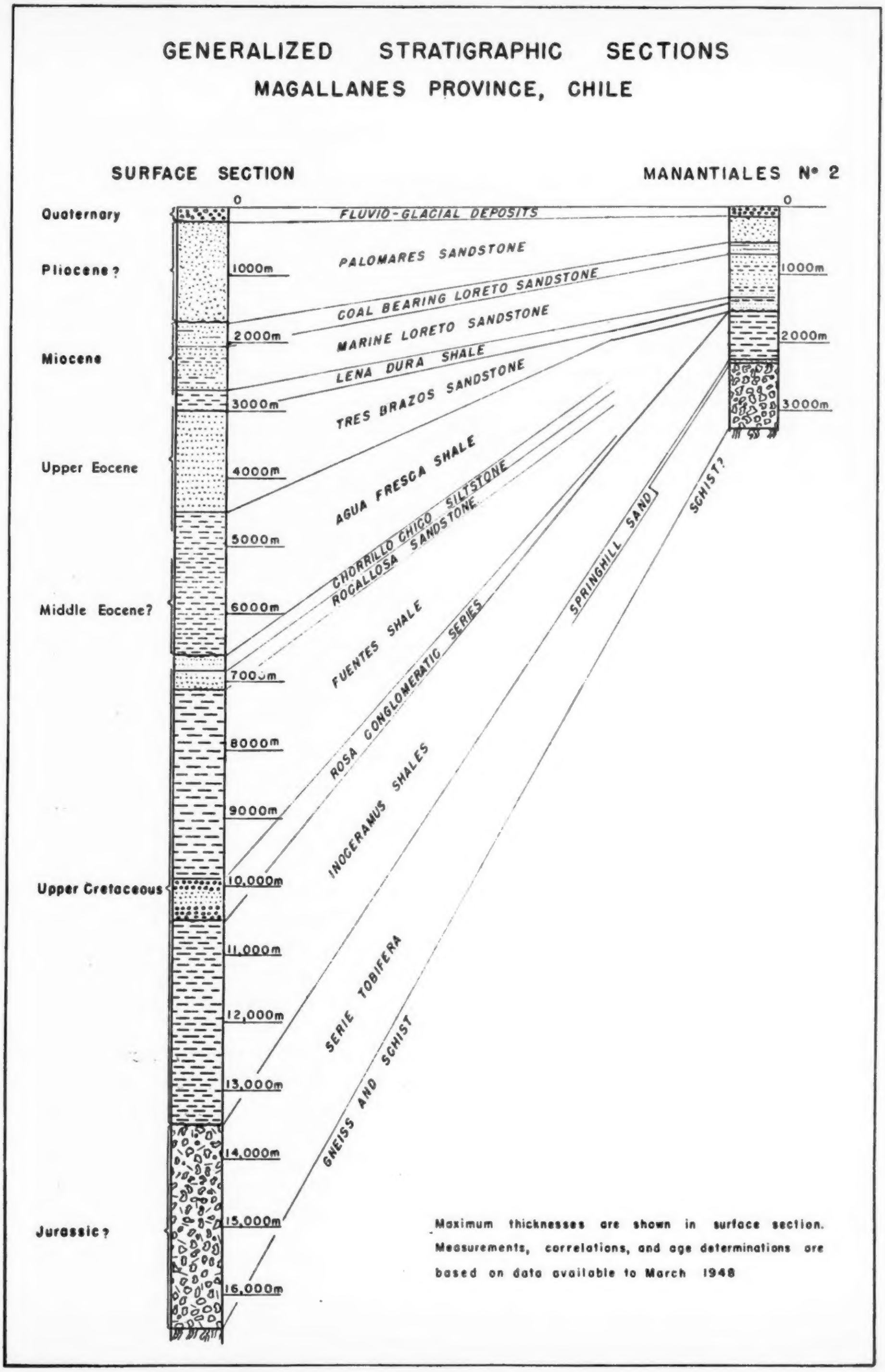


FIG. 3.—Generalized stratigraphic sections, Magallanes Province, Chile.

The Cretaceous-Tertiary contact has been made mostly from reports in the files, but partly from analogy.[16]

The area shown as Tertiary exposures is largely covered by fluvio-glacial deposits and the exposures occur only along the stream valleys.

MAGALLANES BASIN

Judged solely from surface exposures the center of the Magallanes basin should be northeast of Magallanes Province. But the stratigraphy as developed in the Manantiales area demonstrates that such is not the case. Ten thousand meters, or more, of marine sediments dip eastward into this basin. The wells at Manantiales are slightly deeper than 2,200 meters. About 8,000 meters fail to appear at Manantiales. The Cretaceous rocks at Manantiales, about 750 meters thick, are thought to belong to the lower part of the *Inoceramus* shales. The Tertiary rocks include the Tres Brazos, a shale zone above this thought to be the Leña Dura, the Loreto, and Palomares. The entire Agua Fresca, Rocallosa, Fuentes, Rosa, and most of the *Inoceramus* shales are missing (Fig. 3). At San Sebastián, farther southeast, a similar, though shorter section of Cretaceous rocks is found, overlain by the Tres Brazos, the Leña Dura, and part of the Marine Loreto (Fig. 4).

Thus, though the observed facts are few, it is known that a great thickness of sediments, dipping east from the mainland, fails to appear at Manantiales, and much older rocks are structurally higher than could have been expected from strictly surficial studies.

Seismic surveys west from San Sebastián show a consistent southwest dip on the older rocks, as far west as Useless Bay. Insufficient seismic work in the Manantiales area has been done to determine the regional dip west of that area, but the combination of the data, both subsurface and seismic, indicates that this area is along the east flank of the basin.

The Loreto, Leña Dura, and Tres Brazos formations have been deposited on both flanks of the basin, but the Tres Brazos, in at least one locality, has pinched out eastward on the west flank. It is probable that the Tertiary basin does not occupy the same position as the Cretaceous basin, and from what little evidence is at hand to date it appears that the center of the Miocene-Oligocene basin will be found considerably east of the Cretaceous basin.

The variable thickness of the Fuentes shale gives some clues to Cretaceous deposition of that time, but, to date, too little is known of these conditions, though field work recently completed, but not entirely assimilated should throw further light on this matter.

The thinnest section of Fuentes mapped to date is at Horseshoe Bay, which is the small bay inside Bonita Bay along the south shore of Seno Skyring. At this locality 360 meters of Fuentes were measured. Farther east, at the type locality

[16] Recent work has demonstrated a considerable area of Cretaceous exposures on Tierra del Fuego, considerably south of Useless Bay.

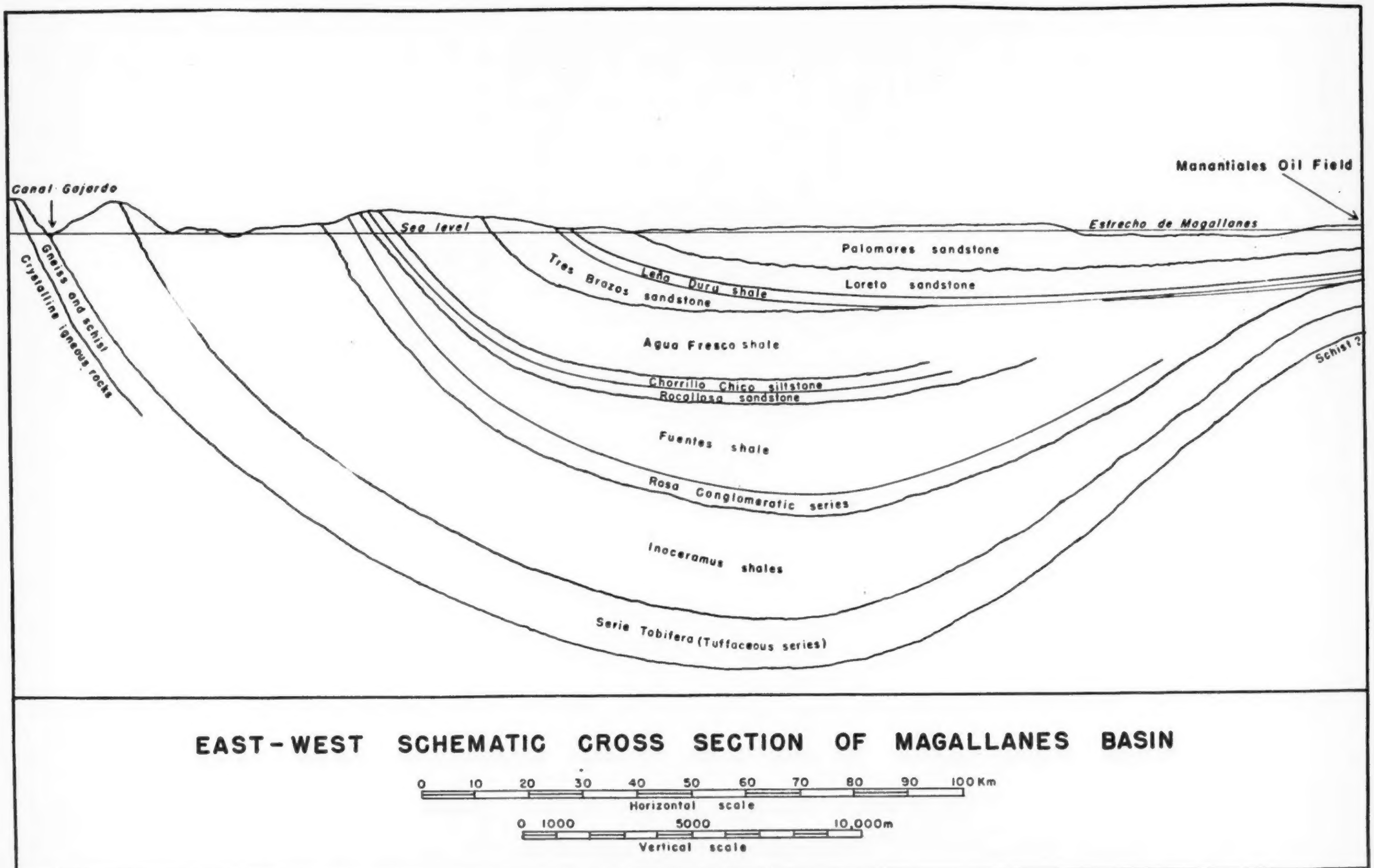


FIG. 4.—East-west schematic cross section of Magallanes basin.

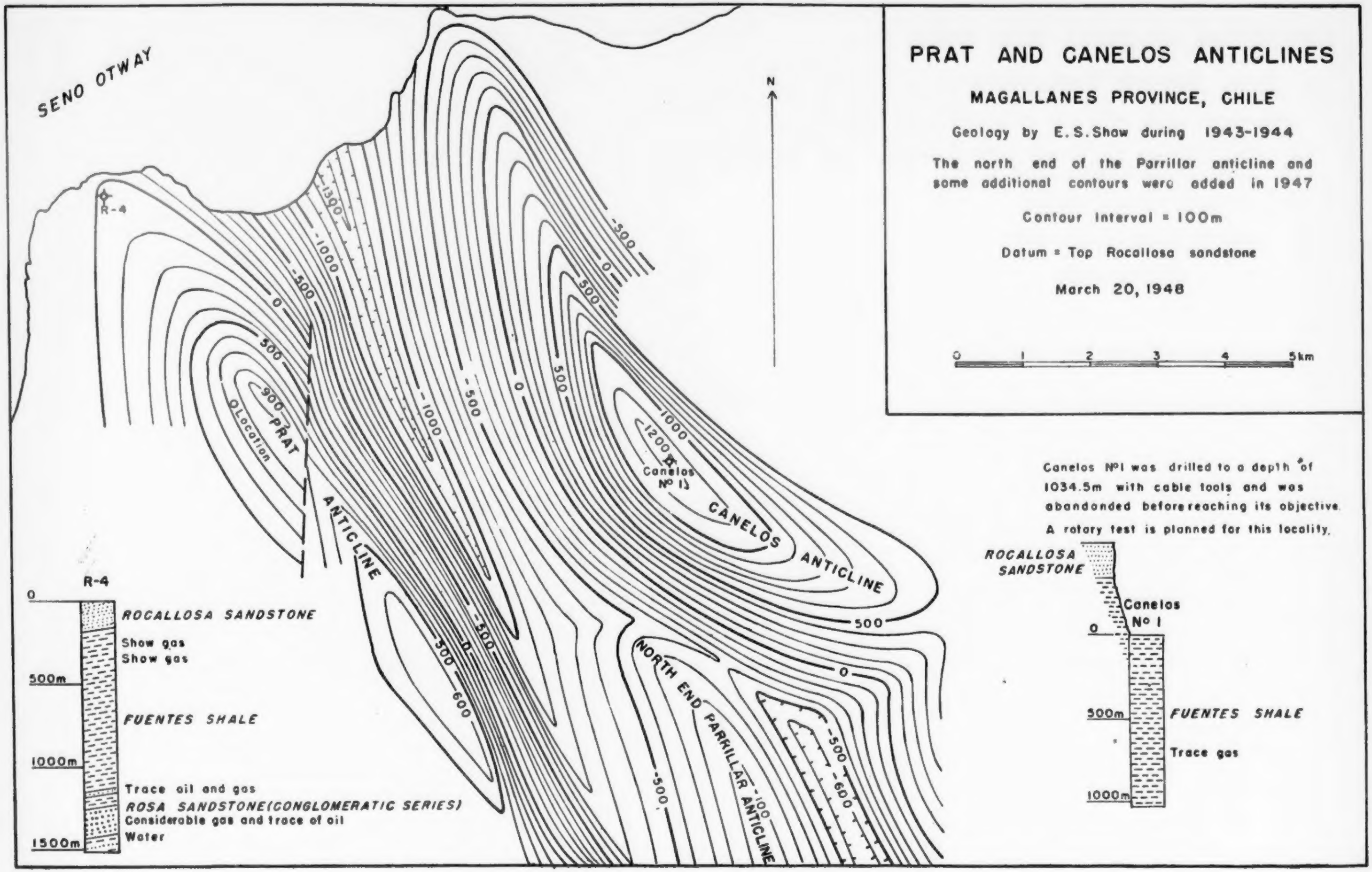


FIG. 5.—Prat and Canelos anticlines, Magallanes Province, Chile.

1,220 meters were observed. Nine hundred meters were penetrated in the R-4 well on Prat Point, but 2,800 meters were measured on Santa Ana Point on Península Brunswick. Recent work in Chorrillo Sur gives a minimum of 2,500 meters plus an estimated 500 meters up to the Rocallosa, and with no base in sight. On Isla Dawson, however, 1,200 meters were measured. Thus it appears that one point along the axis of the Fuentes basin will occur between Santa Ana Point and Isla Dawson, but the direction of this axis is a matter about which no evidence is available at this time, though it might be inferred from the isopachs.

STRUCTURE

The general structure of the Province consists of a series of long steeply folded anticlines and synclines with axis parallel with the strike of the mountains and which diminish in intensity the farther away they are from the mountains. In the Ultima Esperanza area (near Natales and north) these folds have fairly continuous long axes, but are neither so numerous nor so steeply folded as farther south. On Isla Riesco and Península Brunswick, many lines of parallel folding have been observed and most of the anticlines are open on the south end, but many of the synclines are closed. However at least six anticlines with good wildcat prospects, and some others with good closure, but which appear to be fairly close to the metamorphic zone, have been mapped.

Two typical anticlines are shown on the accompanying map of the Prat and Canelos anticlines (Fig. 5). This area was mapped by E. S. Shaw of the United Geophysical Company. However, many additional structure contours have been added to the original work and the original interpretation indicated a thrust fault in the synclines between the two anticlines. More recent studies, aided by aerial photographs, make this latest interpretation more probable.

The zone of steep folding extends east across Isla Dawson, and just south of Estancia Vicuña on Tierra del Fuego very steeply folded beds of *Inoceramus* shale, dipping steeply southward, with practically flat Tertiary rocks exposed not far north, indicate the possibility of a tremendous thrust fault in this area. The lateral extent of this thrust is not known to date as but a few days of field work have been spent in this area.[17]

UNCONFORMITIES

Four major, and some minor, unconformities have been observed above the top of the Serie Tobífera.

The *Inoceramus* shales rest unconformably above the Serie Tobífera, but this contact has been observed in too few places to justify any additional comment.

The Rosa Conglomeratic series rests unconformably on the *Inoceramus* shales and this unconformity must mark a period of considerable diastrophism as

[17] Recent studies indicate the possibility that the differences in dip between the Tertiary and Cretaceous exposures on Tierra del Fuego may be due to an increase in the status of that unconformity rather than to thrust faulting.

boulders as large as, and larger than, one meter in diameter have been observed in this series in the Lago Sofía region, and the closest observed origin for these boulders is at the head of Seno Ultima Esperanza, about 50 kilometers at the west. However, for the most part, the boulders in this conglomerate are 10–30 centimeters in diameter, and smaller.

The Rocallosa sandstone lies unconformably above the Fuentes shale and the great variations in thickness of this shale are explained, at least in part, by this unconformity.

Another great unconformity is just below the Leña Dura shale. The cutting out of the Tres Brazos sandstone between the Río Grande anticline and the Tres Puentes wells indicates the importance of this break.

Unconformities of less importance exist between the Springhill sand and the Serie Tobífera, and between the Chorrillo Chico siltstone and the Skyring shale.

Though important geologically, the unconformity between the Palomares formation and the older rocks appears to have had little to do with the accumulation of oil.

Various unconformities, disconformities, depositional breaks *et cetera*, have been described in the logs of the Manantiales wells, but except for the break between the Tertiary and Cretaceous rocks, and between the Cretaceous rocks and the Springhill sand, these breaks may be considered as minor.

RESULTS OF DRILLING

Few results of a practical nature appear to have been accomplished as a result of wildcatting previous to the advent of the Department of Mines and Petroleum. Nine wells, ranging in depth from 100 to 853 meters appear to have been drilled, but records of their accomplishments have been lost and the locations of many are unknown.

Under the direction of Augusto Hemmer, of the Department of Mines and Petroleum, seven tests were put down in various parts of the province and though no commercial petroleum was discovered, most of these holes were cored from top to bottom and the cores preserved for future examination. In addition good showings of oil and gas were found in three different localities in two different formations.

The first two wells drilled by the Department of Mines and Petroleum were the P-7, on the Tres Brazos anticline, and the R-2, in the Tres Puentes area.

The P-7 was located by the Decat-Pomeyrol commission and though the exposures are too few and too widely scattered to determine the exact position of the axis and the highest point of the anticline, this test appears to have been located fairly close to the axis, and not too far from the crest, of a large closed anticline. This test started and stopped in the Agua Fresca shale at a total depth of 1389.6 meters. It is felt that deeper drilling would have been justified as this is considered as being a good location for testing the Rocallosa sandstone.

The R-2 well, started at the same time as the P-7, was located largely from

core-drill information, and was drilled to the total depth of 1,177 meters. It started in the Loreto sandstone, drilled through the Leña Dura shale, missed the Tres Brazos sandstone, and stopped in the upper Agua Fresca shale. Good showings of oil and gas were found in the Loreto sandstone and it was thought that it was too high structurally to produce oil. The R-5, deliberately placed farther down on the east flank, was drilled to the total depth of 782 meters, but had poorer showings than the R-2. The R-6, drilled at a much later date, was in the same vicinity, and was drilled to the total depth of 1,729 meters, stopping in the middle Agua Fresca shale.

The tools from P-7 were shipped to Prat Point and drilled the R-4 test. This well was located well down from the top of the anticline, but in spite of this fact it had good showings of oil and gas in the Rosa sandstone. It started in the Rocallosa sandstone, drilled through the Fuentes shale, and stopped either in Rosa Conglomeratic series or in the *Inoceramus* shales. Its total depth was 1,508 meters. The location of this well is shown on the map of the Prat and Canelos anticlines (Fig. 5).

The R-1 test, not far east of Mina Elena on the north shore of Isla Riesco, was drilled to the total depth of 602 meters, and started and stopped in the Agua Fresca shale. It was located along the axis of an anticline, the south part of which had closure and the north part of which was under the waters of Seno Skyring. Since all the other folds on Isla Riesco plunged north, it is probable that this anticline also had north closure, but this can not be proved except by expensive water seismic work. This test is considered to have had fair possibilities.

The S-5 test, near Estancia Pecket, on Península Brunswick, was located by core drilling. It was drilled to the total depth of 912 meters, starting and stopping in the Loreto sandstone. Good showings of oil and gas were found from 408 to 460 meters.

EXPLORATORY WELLS DRILLED BY CORPORACIÓN DE FOMENTO

Not being certain as to which type of rig would be most successful in this territory the Corporación de Fomento imported cable tools as well as rotary tools for its first operations.

The first cable-tool operation was Mina Rica No. 1. This well was located on a seismic anticline and was intended to test the Tres Brazos sandstone, 1,500 meters of which were exposed on the Río Grande anticline, not far west, but the rapid and unexpected convergence of this sandstone toward the east rather dimmed its prospects of accumulation. This well started in the Leña Dura shale, drilled through the Tres Brazos sandstone, of which there were only 175 meters, and into the upper Agua Fresca shale. Its total depth was 571.2 meters.

The first rotary test was on a seismic high at Manantiales, near the north end of Tierra del Fuego. This test drilled 82 meters of glacial gravel, had Tertiary rocks to 1,496 meters, Cretaceous rocks to 2,258.6 meters, and drilled into the Springhill sand with the total depth of 2,267.1 meters. Oil in large quantities was found in this sand.

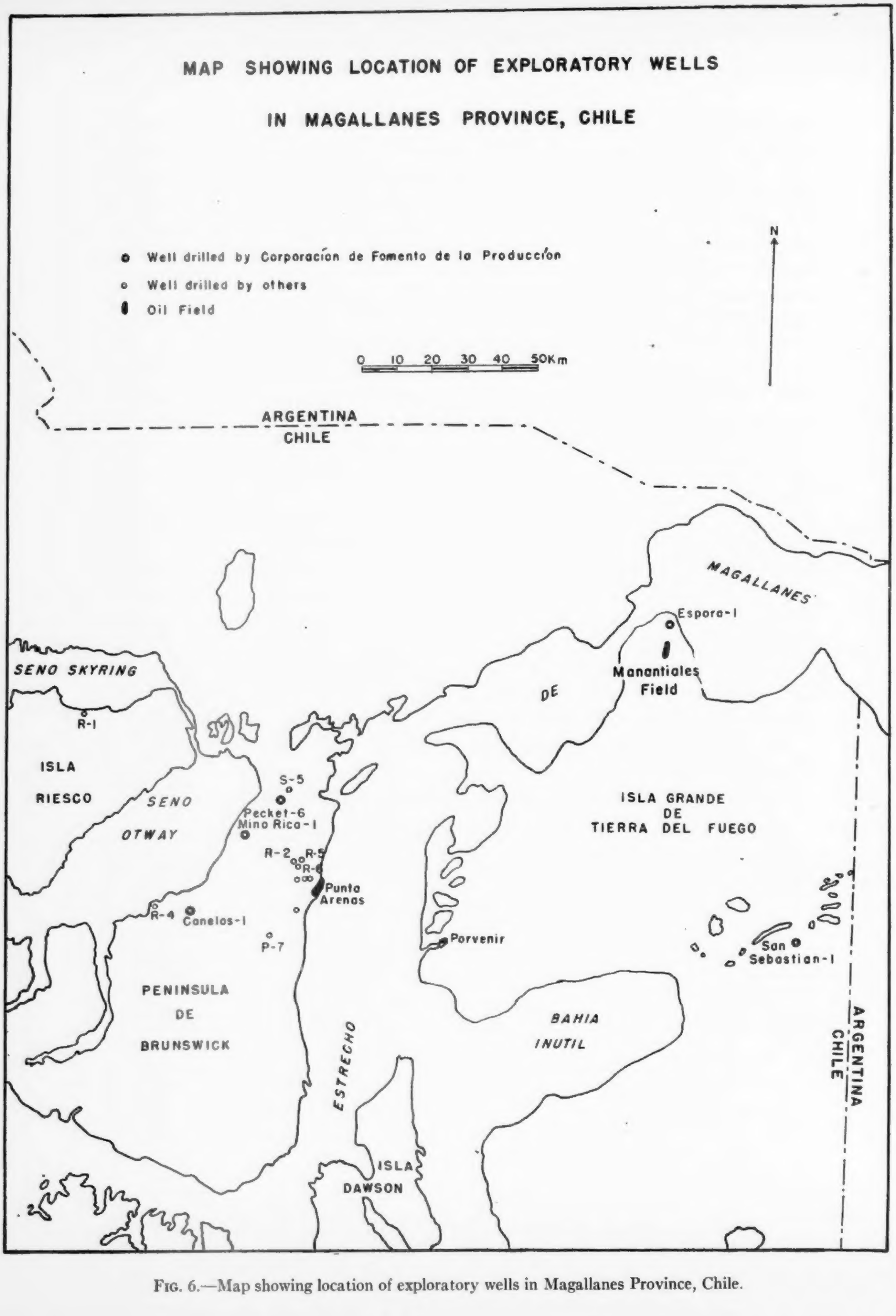


FIG. 6.—Map showing location of exploratory wells in Magallanes Province, Chile.

The second cable-tool test was also located on a seismic high. This was Pecket-6, not far southwest of S-5. It was drilled to the total depth 999 meters, starting in the Loreto and stopping in the top of the Leña Dura shale. No good showings of oil or gas were found in this test but lithological examinations by H. T. Kniker indicate that the Loreto deposits in this vicinity were more continental than those in S-5 and this fact may account for the poorer showings.

The third cable-tool test was Canelos No. 1. The location of this test is shown on the map of the Prat and Canelos anticlines (Fig. 5). This test drilled to the total depth of 1,034.5 meters and started and stopped in the Fuentes shale. It had not reached its objective, and this fold is not considered as having been tested, but testing in the future will be done with rotary equipment.

During this year (1948) three additional rotary wildcats have been drilled. All were located on seismic highs: two at San Sebastián and one at Espora.

Espora No. 1, about 8 kilometers north of the Manantiales field, drilled through a section similar to Manantiales, appeared to be on a continuation of the same fold, was 160 meters higher structurally, had 33 meters of very favorable-appearing Springhill sand, but made water. The top part of the sand, however, did have a slight amount of oil, and acted very much as did Manantiales No. 4 which is just one location outside the oil zone. More work has been done in this territory and another location recommended at the west. This second location will be drilled shortly.[18]

San Sebastián No. 1, about 90 kilometers southeast of the Manantiales field, encountered a similar thickness of Tertiary rocks, but started much lower in the Loreto sandstone. The total section of Cretaceous rocks was some thinner than at Manantiales, but the correlations were made fairly easily. This well encountered the Springhill sand at 2,107 meters, found 19 meters of oil-saturated sandstone, and drilled some distance ahead in the Serie Tobífera. It produced very little fluid. SS No. 2 also produced very little.

OCCURRENCES OF OIL AND GAS

Numerous gas seeps have been found on Península Brunswick and on Isla Riesco.

The only authentically reported oil seep known to date is in the Tres Puentes area in which oil is reported as seeping from the Loreto sandstone.

Showings of oil and gas have been encountered in Tres Puentes wells, and in the S-5 wells from the Loreto sandstone.

Showings of oil and gas were encountered in the Rosa sandstone in the R-4 well.

Reports from field geologists report many strong odors of oil from many surface exposures of the Rocallosa sandstone and from many different localities.

[18] Since the writing of this paper, Espora No. 2, located 900 meters west and slightly north of Espora No. 1, on a 24-hour test, with $\frac{3}{8}$-inch choke, made 1,500,000 cubic feet of gas and 90 barrels of 50° oil. It is only 4 meters higher, structurally, than No. 1.

Oil has been found in considerable quantity in the Springhill sand in the Manantiales field, a small showing in the same sand was found at Espora, and 19 meters of saturated oil sand were found at San Sebastián.

Thus, showings of oil and gas, or oil and gas in commerical quantities, have been found in three different zones, in widely scattered territories. In addition, another zone has given off strong petroleum odors in many localities.

POSSIBLE RESERVOIR ROCKS

The Serie Tobífera, which is considered as the approximate equivalent of the Serie Porfírica of Argentina, is not without possibilities as oil is produced from that series in Argentina. Gas from Manantiales No. 11 comes from the top of this series, but this is only a couple of meters below the Springhill sand. Oil stains were found in this series below the Springhill sand in San Sebastián No. 1, but, to date, no test has been made. Until more is known of this formation it can not be considered as beyond the pale.

The Rosa Conglomeratic series offers considerable potentialities as a reservoir rock because of its widespread occurrence and the fact that both oil and gas were encountered in considerable quantity in R-4, even though this well was located very poorly structurally. Though most exposures of this formation show the conglomerate as being very well cemented, thus lessening the pore space, in some localities no cement is visible, and the fact that the hole full of water was encountered below the oil showings in R-4 indicates a reasonable amount of porosity in this formation. In addition, the great thickness, 140–500 meters, would allow a comparatively non-porous sandstone to contain a great quantity of oil.

The Rocallosa sandstone, while untested to date, has been recorded in many localities as containing strong oil odors. Though more shaly than the Rosa an average of 220 meters in thickness should lend some degree of hopefulness to its possibilities as a reservoir rock.

The Tres Brazos sandstone, because of its convergence in the direction of the regional dip, has attained very little depth in most localities on the continent before it disappears. For this reason the drainage area of any anticline located within its boundaries, on the continent, will be small. Thus, though a thick, fairly porous sandstone, with good thicknesses of marine shale both above and below, its prospects appear dim insofar as any locations made on the continent. However, asphalt, and stains of heavy oil have been found in this zone in the Manantiales field, and this zone is not without possibilities on the east flank of the basin.

The Loreto sandstone has demonstrated excellent possibilities and very probably will be found a good reservoir rock, but the problem at the moment is to find this sandstone, with good structure, with good cover, and with sufficient depth to justify testing.

The Springhill sand, since it is the only commercial producing zone encounttered to date, is, of course, the most important at this time. In the Manantiales field this sand body is converging westward, and while the size and the extent

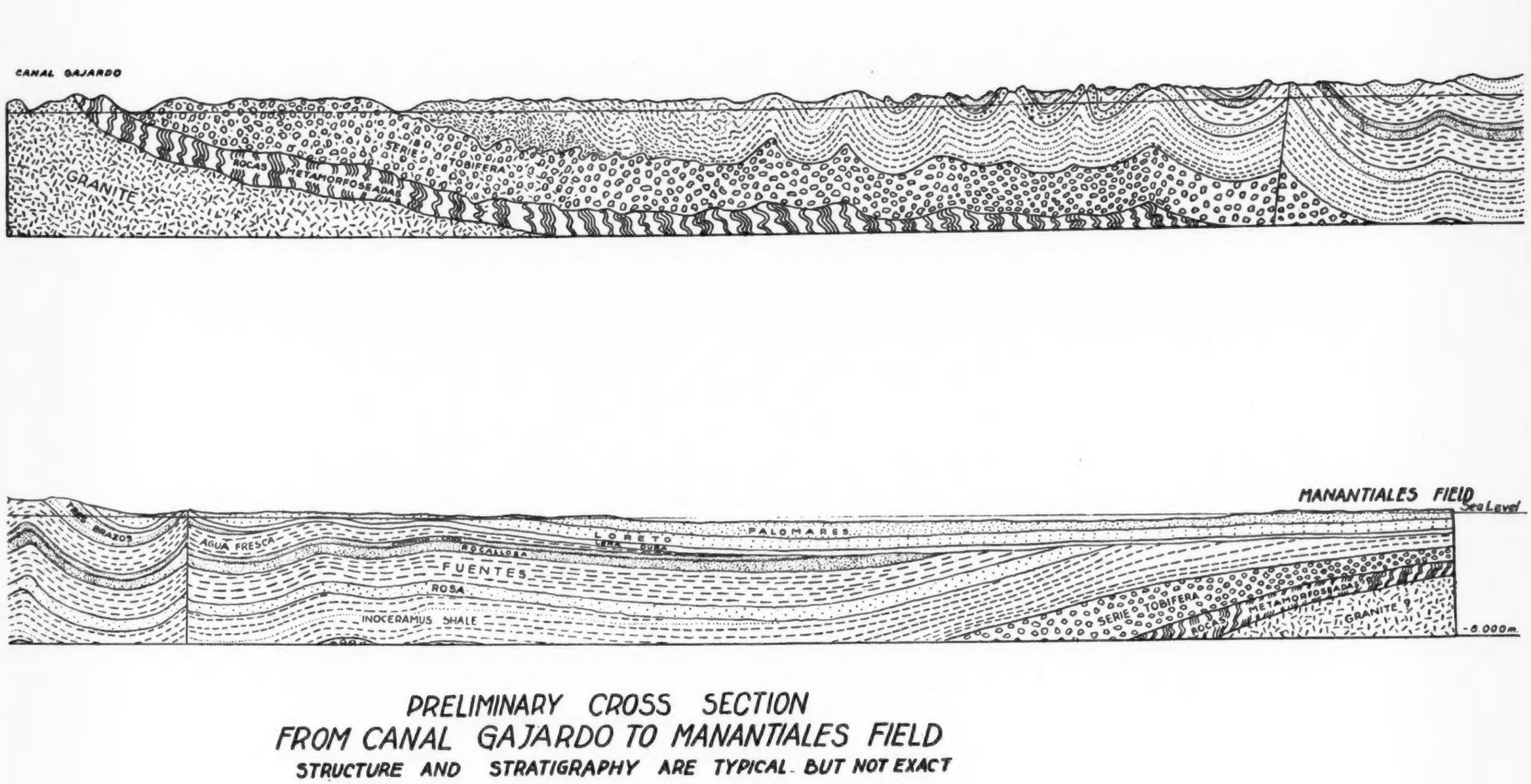


FIG. 7.—Preliminary cross section from Canal Gajardo to Manantiales field.

of this formation is unknown, the 33-meter section found at Espora, 8 kilometers north, and 19 meters found at San Sebastián, 90 kilometers southeast, give a reasonable hope of its being fairly widespread.

SOURCE ROCKS

The writer is not prepared to accept the premise that the quantity of oil that may be accumulated in a basin is invariably directly proportional to the cubic volume of the marine sediments contained therein, but in the absence of other data he considers this factor of the highest importance.

In this province there is a comparatively small, but deep depositional basin, with 12,000 to 14,000 meters of marine sediments measured on one flank, which are dipping into this basin. However inefficient they may be, or may have been, any trap within this basin has, quantitatively, an ample source for petroleum.

Insofar as possibilities are concerned, the record of the wildcatting to date indicates considerable potentialities. Of the seven wells located by the Department of Mines and Petroleum, three good showings, in two different zones, were encountered. Of the seven wildcats drilled by the Corporación de Fomento, and which were located by more modern methods, one oil field, one saturated core, one well which indicates definite prospects in the vicinity, and one uncompleted well, are the results. Though some years of geological and geophysical prospecting have produced only a fraction of the geological data to be known, these figures indicate an ample supply of source rocks in this province.

FUTURE POSSIBILITIES

The problem as to what happens to the eastward-dipping rocks on Península Brunswick, and which do not appear at the Manantiales field, is of considerable importance insofar as future expectations are concerned. The Rocallosa and Rosa formations have been recorded on Isla Dawson. Some slight evidence exists which leads to the belief that this locality is on the east flank of the Cretaceous basin. If such be the case the possibilities of the upturned and truncated edges of these sandstones being found on the east flank of the basin are not too remote.

If such should be the case the possibilities of long stratigraphic traps become good. It must be admitted, however, that such conditions are hopes rather than expectations.

Regardless of what may happen, wherever the section has been measured, porous sandstone, with very thick sections of marine shale both above and below, has been found scattered throughout the section. No locality is known wherein it is considered that the drill would not encounter some porous zone within reasonable depths.

Insofar as stratigraphic traps are concerned, their discovery will be by accident or after many tests have been drilled and the knowledge of the subsurface conditions is much greater than at present.

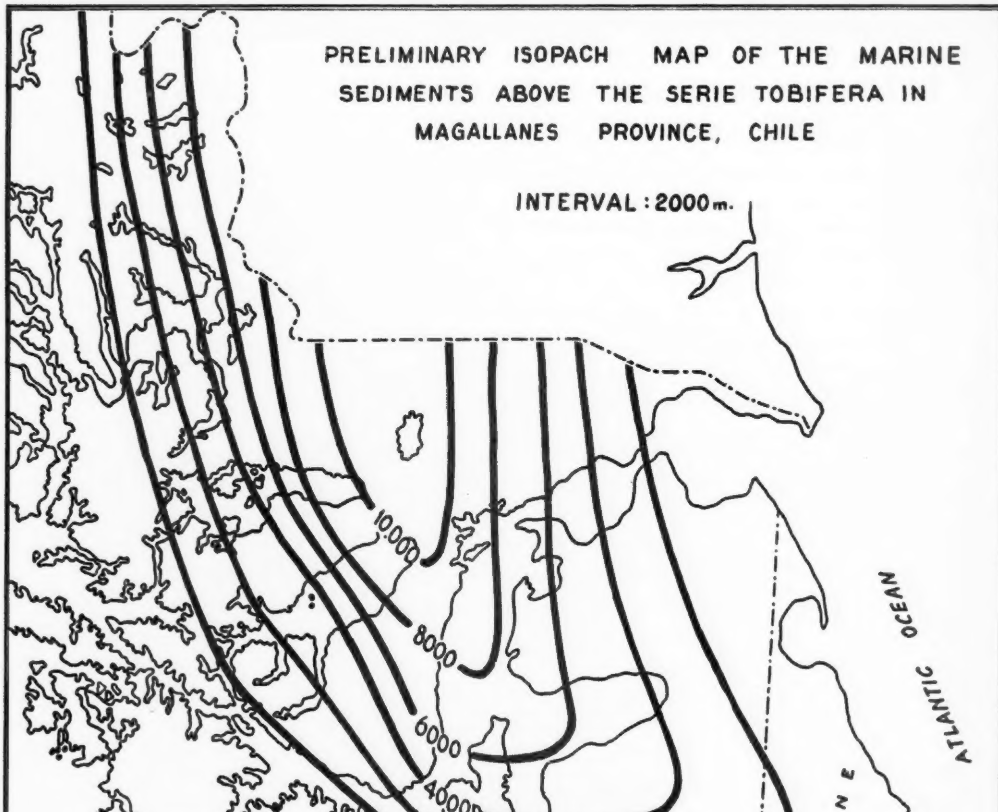


FIG. 8.—Preliminary isopach map of marine sediments above Serie Tobífera in Magallanes Province, Chile.

Regardless of theorizing, the facts themselves lend credence to the following very good hopes.

Source rocks.—A very thick section of marine sediments.

Reservoir rocks.—A number of thick sandstones, two of which have had excellent showings of oil and gas, another of which has given off strong odors of petroleum, and a comparatively thin one (30 meters) which has produced oil in commercial quantities in one locality and which promises to do so in another.

Unconformities.—Four major and a number of minor unconformities have been recognized.

Folding.—Folding, on a large scale on the western flank, but on a smaller scale (insofar as local closure is concerned) on the eastern flank of the basin has already been determined. The conditions in the center of the basin are entirely unknown to date.

Oil occurrences.—One oil field, another area with oil saturated sand but low permeability, showings of oil and gas in two different zones, in three different localities on the continent.

From these facts it would be difficult to assume that all the oil had already been found, but the assumption that the reserves had barely been scratched could readily be justified.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 33, NO. 9 (SEPTEMBER, 1949), PP. 1579-1589, 11 FIGS.

MANANTIALES FIELD, MAGALLANES PROVINCE, CHILE[1]

C. R. THOMAS[2]
Punta Arenas, Chile

ABSTRACT

The discovery well found oil in December, 1945. It was known as Springhill No. 1, but the name of the field, by Presidential Proclamation, was later changed to Cerro de los Manantiales. This well was located on a seismic high.

It is probable that the basement rocks in this area were reached in Manantiales No. 2, but this is not definite. About 1,000 meters of the Serie Tobífera, 10–35 meters of the Springhill formation, 750 meters of Upper Cretaceous rocks, and about 1,500 meters of Tertiary and Quaternary rocks are present in this locality.

The structure, according to the seismic map, is fairly large. Development, to date, has generally followed the seismic picture, but these data, due to poor records, are not sufficiently accurate to make new locations.

Some small faults, which may well affect the accumulation, have been observed in the area. At least one of these extends upward into the Tertiary rocks.

The oil is high-gravity, about 42° Bé., and the gas is rich in gasoline. Due to lack of storage, no lengthy tests have been made, but most of the oil wells have produced 25–35 barrels per hour on ¼-inch choke. Their ultimate capacity is not known but it is much greater than this.

LOCATION AND HISTORY

The Manantiales field is located near Península Espora on the north end of Isla Grande of Tierra del Fuego, Magallanes Province, Chile.

The discovery well was commenced, September 22, 1945, and on December 29, 1945, found oil at a depth of 2,259 meters. This well was drilled by the Livermore Corporation under contract to the Corporación de Fomento de la Producción. It was located on a seismic high mapped by L. K. Morris. Glen M. Ruby was in general charge of the explorations. Eduardo Simián was chief engineer, and Jorge Pacheco assistant chief engineer, for the Corporación de Fomento.

At that time it was known as Springhill No. 1, but at a later date, by Presidential Proclamation, the name of the field was changed to Cerro de los Manantiales (Hill of the Springs). This name, by universal custom, has been shortened to Manantiales.

STRATIGRAPHY

It is probable that the basement rocks have been reached in Manantiales No. 2 but since no core was taken this is not certain. A great quantity of mica schist was found in the sample at 3,293.4 meters, and the drilling time was much greater than usual, but since similar material had been drilled through farther up the hole, this conclusion is not definite. Because the machinery had been pushed to the limit it was considered inadvisable to re-enter the hole with the core barrel.

[1] Read before the Association at St. Louis, by Clark Millison, March 17, 1949. Manuscript received, March 29, 1949. Published by permission of the Corporación de Fomento de la Producción, Chile.

[2] Head of the exploration department in Magallanes Province for the Corporación de Fomento de la Producción.

SERIE TOBÍFERA

About 1,000 meters of rocks referred to the Serie Tobífera were encountered in this area. This series is primarily composed of sedimentary volcanic ash, but has thin streaks of carbonized wood, hard, dark, siliceous shale, rare feldspar crystals, numerous quartz and calcite crystals, considerable chlorite, and near the base considerable reworked mica schist. Thin streaks of orchid-colored shale were encountered near the middle of the formation, and a 30-meter sandstone near the top. This sandstone was composed of coarse, rounded, frosted, quartz grains, well cemented with soft kaolinitic shale. After the casing was set below the top of the series, in No. 2, *Inoceramus* prisms were encountered.

SPRINGHILL FORMATION

The Springhill formation rests unconformably on the Serie Tobífera and is composed largely of material derived from that formation. It varies from 10 to

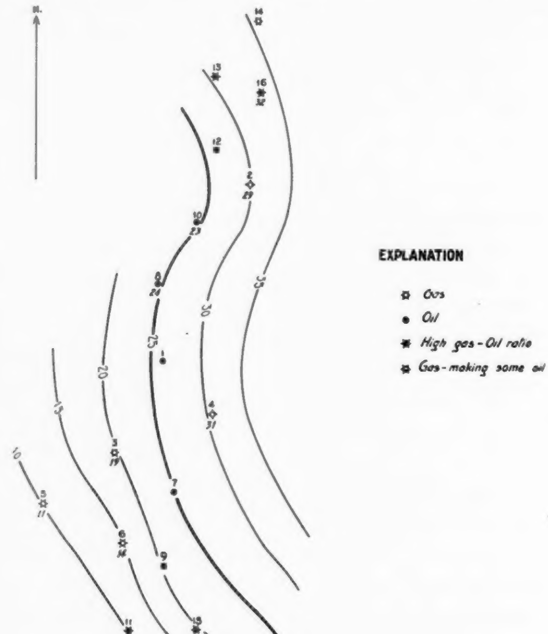


FIG. 1.—Isopach map of Springhill formation, Manantiales field. Contour interval, 5 meters.

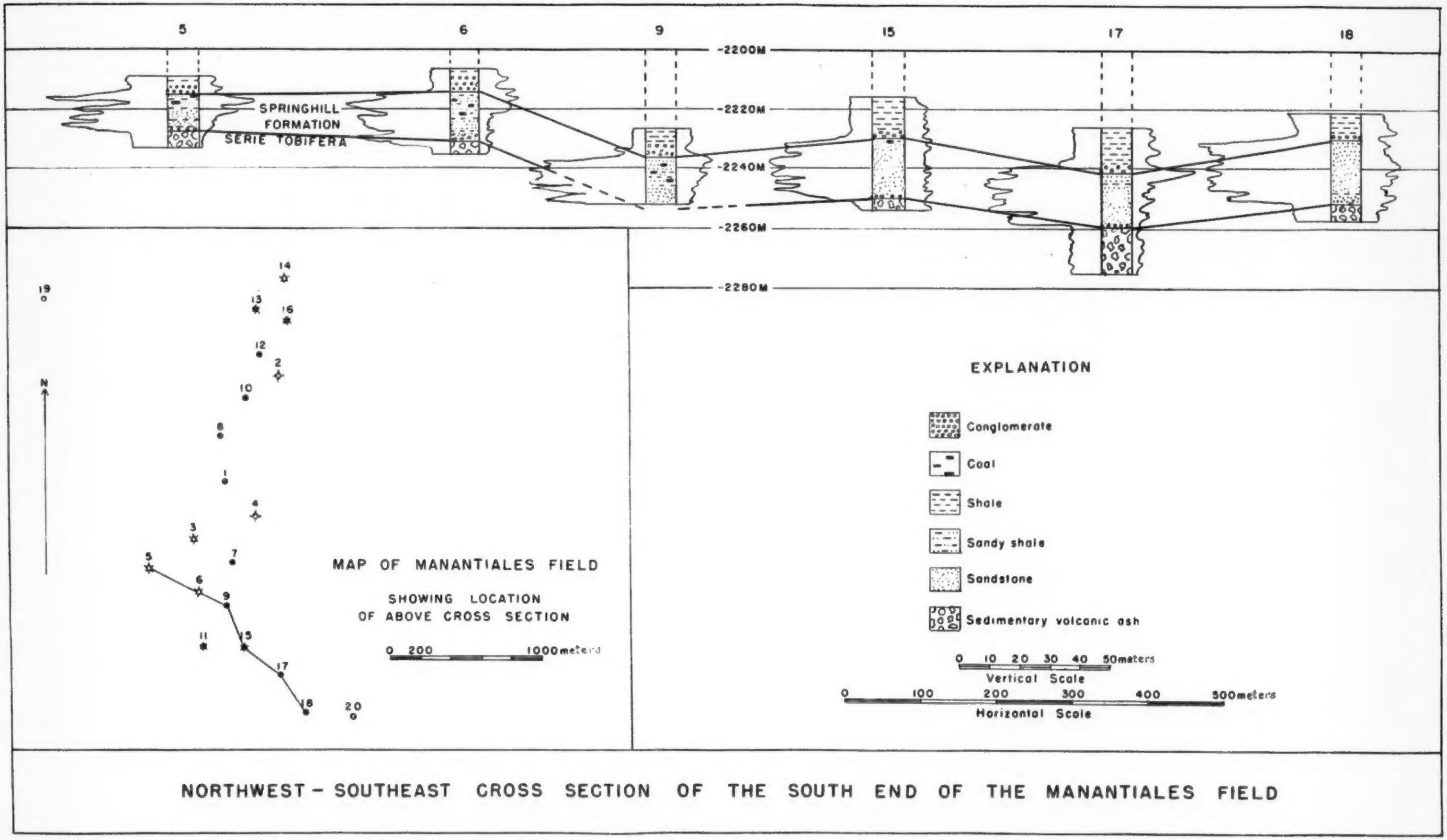


FIG. 2.—Northwest-southeast cross section of the south end of Manantiales field.

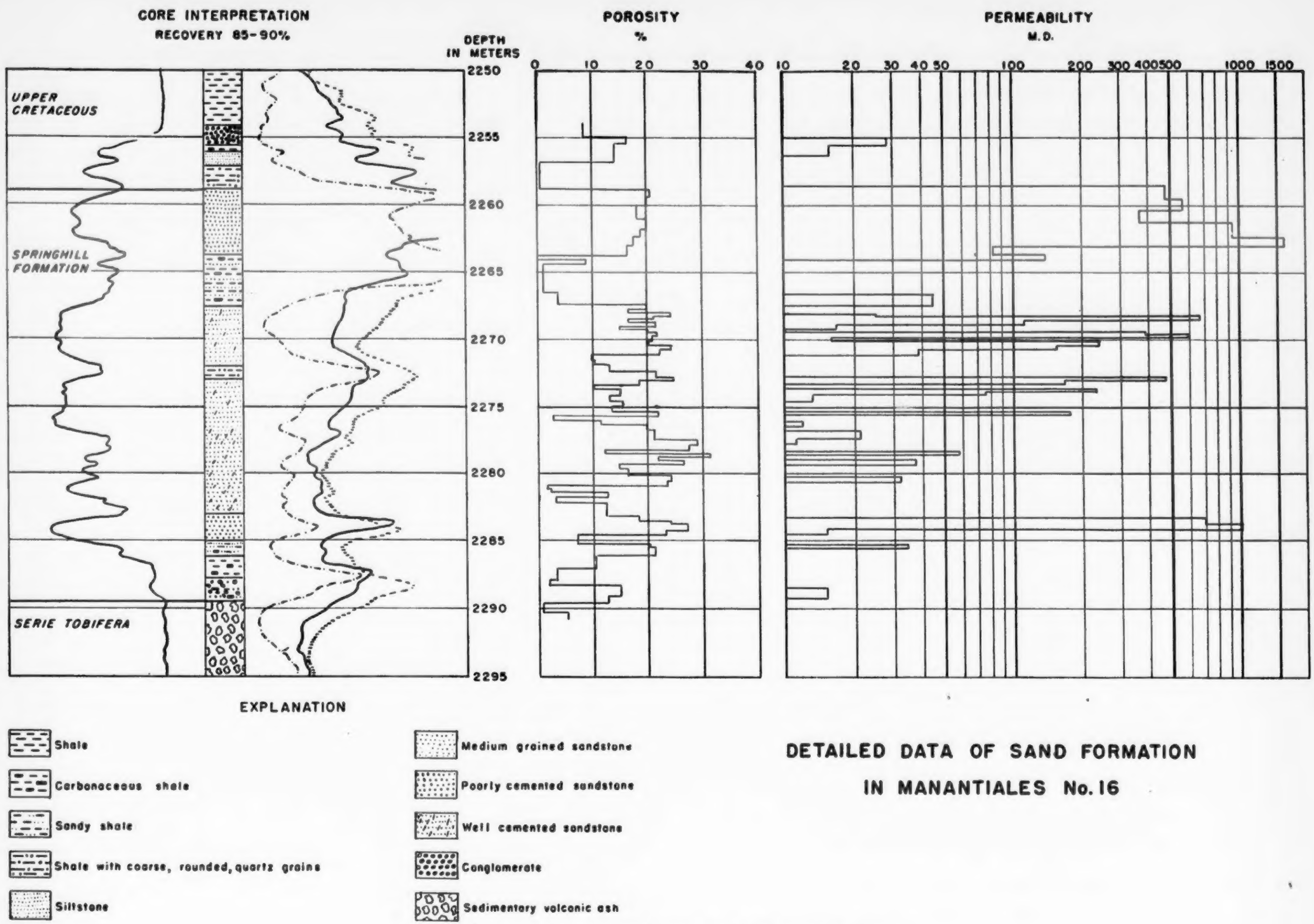


FIG. 3.—Detailed data of sand formation in Manantiales No. 16.

35 meters in thickness as well as considerably in character. In the western part of the field a large part of the formation is coal and coaly shale. In the eastern part of the field it is mostly sandstone. However, a basal conglomerate has been observed in all parts of the field, as well as some meters of reasonably porous sandstone. Fortunately, the sandstone improves in quality as well as thickens toward the east, which is the area of the oil accumulation. Studies have not yet been completed on the deposition of this sand, and the available data are insufficient to prove any definite conclusion, but the writer's opinion is that most of this sand is a near-shore deposit with a sand bar on the east and a lagoon on the west.

The sand itself is variable in character, some parts being free from cement and porous, and other parts well cemented with kaolinite and kaolin. That part which is free from cement consists of interlocking quartz crystals, which appear to be the result of secondary recrystallization.

FIG. 3.—Detailed data of sand formation in Manantiales No. 16.

UPPER CRETACEOUS ROCKS

The oldest Upper Cretaceous rocks observed in the field appear to be of Eagle Ford age. Resting unconformably above the Springhill formation is a conglomerate ranging from 1 to 7 meters in thickness. Primarily this consists of dark, carbonaceous, glauconitic shale containing coarse, rounded, quartz grains, but also thin streaks of white siltstone and very fine-grained sandstone and some thin streaks of soft gray shale have been observed.

The carbonaceous material is thought to be the reworked coaly material from the upper part of the Springhill formation.

Various markers have been discovered in these rocks. These range from the glauconitic limestone, about 20 meters above the top of the Springhill formation, through the glauconitic sandstone, speckled shale, the hard chalk, and the *Inoceramus* zone. The *Inoceramus* zone is the highest Cretaceous marker, but though some idea of the relative position of the sand can be had from the other markers, this zone appears to have been relatively free of folding, and, to date, has been of little value as a marker. These rocks consist primarily of gray waxy shales with a few thin limestone streaks and one thin sandstone.[3]

The oldest member is considered to be Eagle Ford in age and the youngest Taylor. The thickness, in this area, is about 750 meters.

Above these Cretaceous sediments is a 50-meter section of rocks whose age is controversial. These are gray shales lithologically similar to those above and below, but without any diagnostic fossils. The picture on the electrical log is similar to those below.

TERTIARY

The oldest Tertiary rocks recognized in this area is the Tres Brazos sand-

[3] Two wells recently completed considerably west of the previous development demonstrate folding on the *Inoceramus* zone (Taylor age). Furthermore, both wells had more than 30 meters of sand with practically no coal.

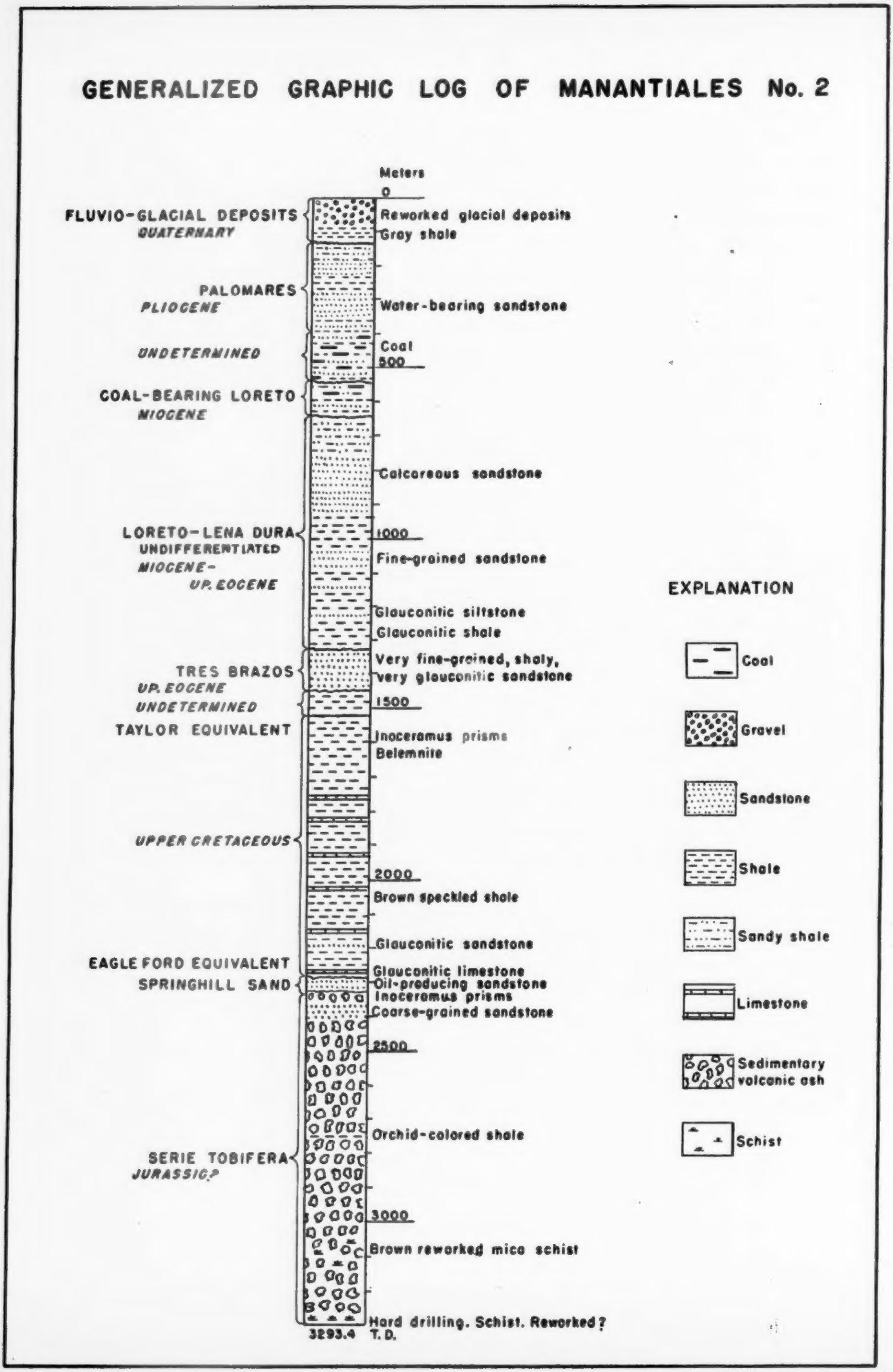


FIG. 4.—Generalized graphic log of Manantiales No. 2.

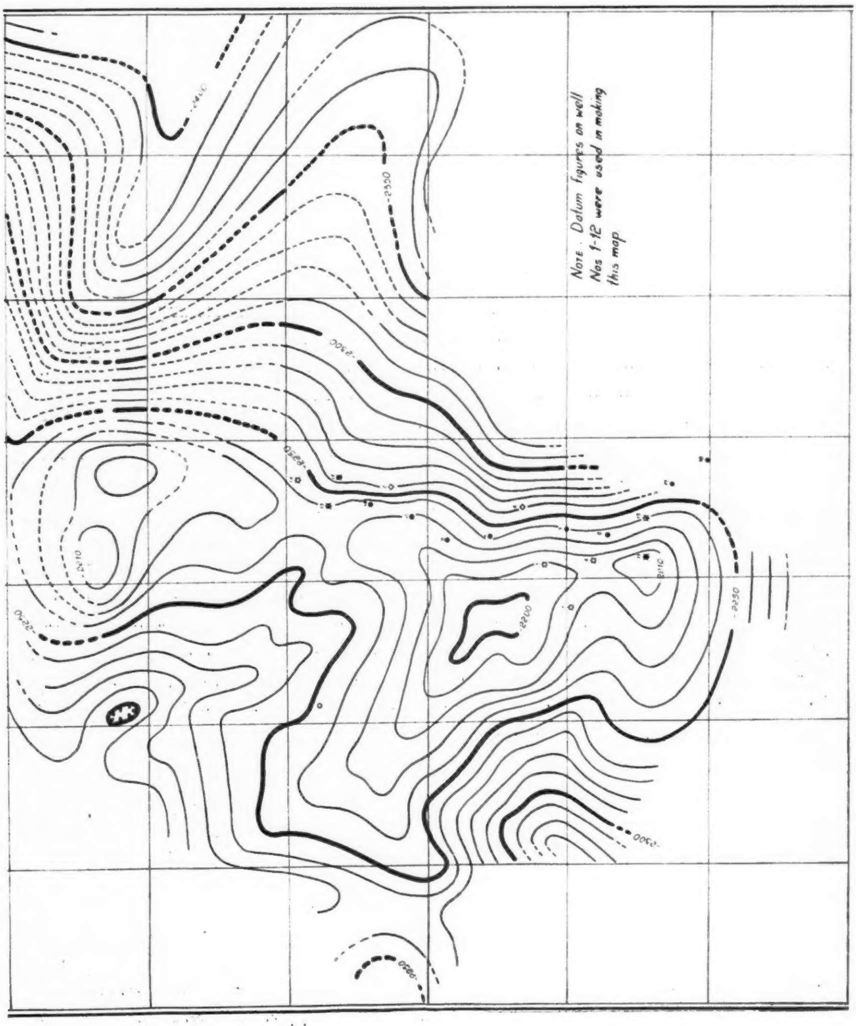


Fig. 5.—Seismic map of Manantiales field. Contour interval, 10 meters. Datum, reflection at depth of Springhill sand. Seismologist, L. K. Morris. April 15, 1948. Scale: $\frac{13}{16}$ inch equals approximately 1 kilometer.

stone. This is a series about 125 meters thick and consists of very fine-grained, shaly, very glauconitic sandstone.

That part of the section above the Tres Brazos sandstone has previously been correlated with the Loreto and Palomares, but surface work now in progress indicates the possibility that there may be rocks older than Loreto which may or may not be as old as Leña Dura, just above the Tres Brazos. Also the contact between the Palomares and Loreto is subject to some question. There will undoubtedly be some changes made in the correlation of these beds, but such changes will be made only after the completion of the work now in progress.

The fluvio-glacial deposits at the surface consist of reworked gravel underlain by soft gray shale.

STRUCTURE

The size, shape, and extent of the anticline may be inferred from the seismic map (Fig. 5), but the poor quality of the seismograms precludes any definite interpretation of the reflections and consequently this must be taken as an inference and not as an established fact. However, No. 19, now drilling on the west side of the field should give some reliable data about the extent of the folding.

Structure maps (Figs. 6–10), based on sample and electrical-log interpretations, show at least one fault which has affected the Tres Brazos. The fault shown at the south end of the field has been traced in a number of wells, but development to date has not been far enough toward the south for it to have cut the sand. Its effect on the accumulation is not yet known. The fault in the middle of the area has definitely been located in No. 8, and some slight evidence exists which could place it well up in the Tertiary in No. 1. The fault at the north end of the field is the most problematical of all inasmuch as the data on which it is based might as readily be interpreted as depositional variations. If faulted, in No. 16, there would need to be a series of three small faults, in place of one large fault. However, the isopach map on the interval between the *Inoceramus* zone and the Springhill formation indicates the possibility of this interpretation.

The folding that took place appears to have started during Eagle Ford time, and to have been nearly finished by Taylor time. Faulting, however, has extended somewhat up into the Tertiary (Oligocene).

HISTORY OF DEVELOPMENT

The original seismic map was known to be of a reconnaissance nature and after the discovery of No. 1 it was thought best to extend the field in fairly large jumps. No. 2 was located 800 meters (½ mile) northeast from the discovery. It was structurally low. Nos. 3, 4, 5, and 6 were located in an effort to outline the productive area, but by that time a detailed seismic map had been made and No. 8 was located on seismic data. No. 7 was located on sand-datum figures. The seismic data were also used for locating many of the other wells but after No. 11 came in as the highest well at that date it became apparent, that, though out-

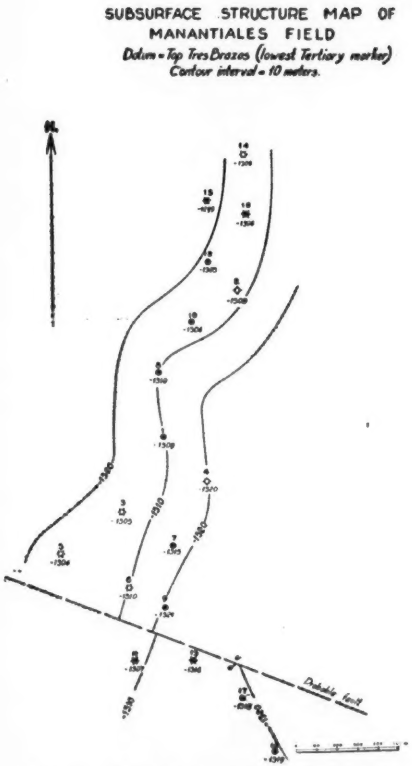


FIG. 6.—Subsurface structure. Datum, Tres Brazos. Scale: $\frac{1}{8}$ inch equals 100 meters.

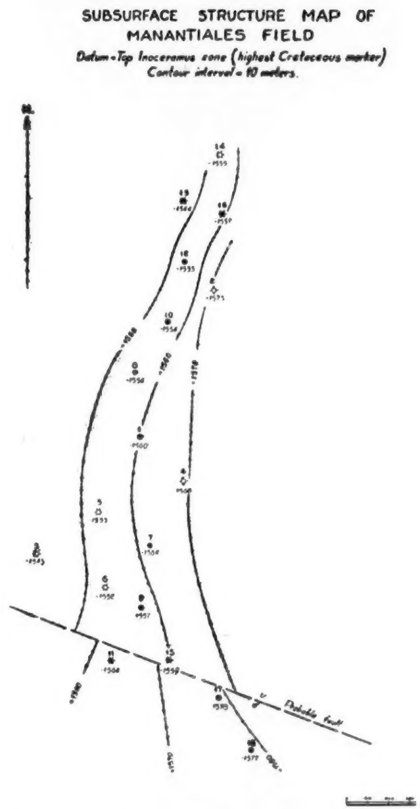


FIG. 7.—Subsurface structure. Datum, *Inoceramus* zone. Scale: $\frac{1}{8}$ inch equals 100 meters.

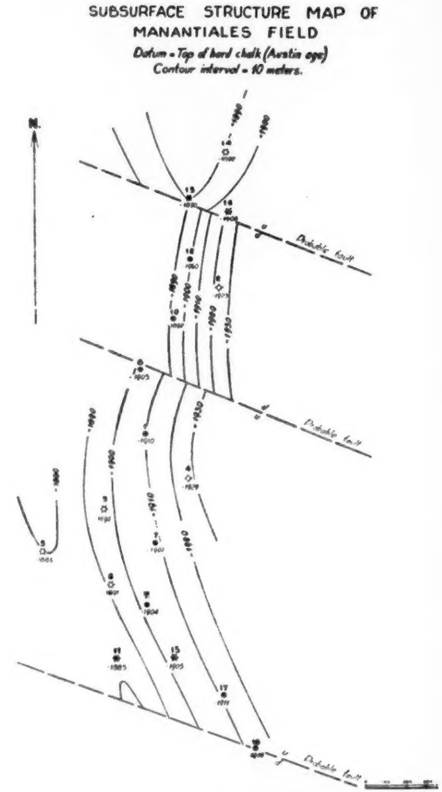


FIG. 8.—Subsurface structure. Datum, hard chalk. Scale: $\frac{1}{8}$ inch equals 100 meters.

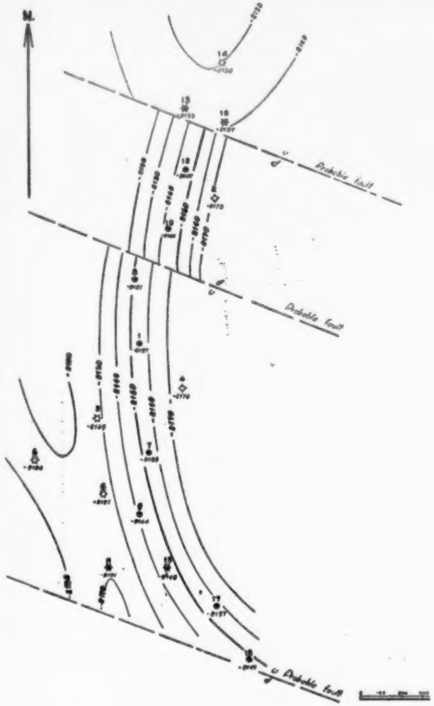


FIG. 9.—Subsurface map. Datum, glauconitic sandstone. Scale: $\frac{1}{8}$ inch equals 100 meters.

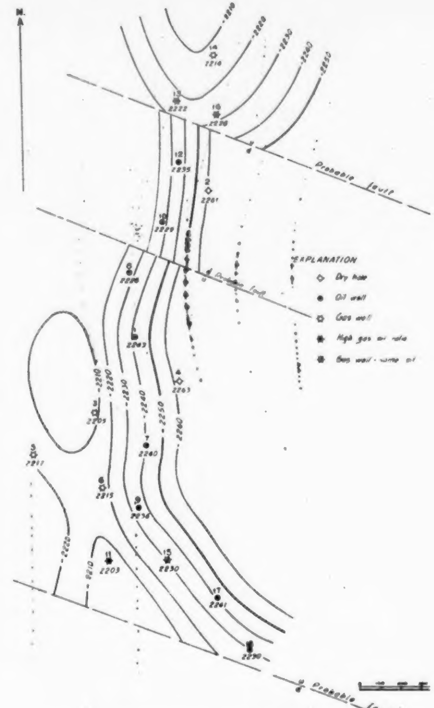


FIG. 10.—Subsurface map. Datum, Springhill formation. Scale: $\frac{1}{8}$ inch equals 100 meters.

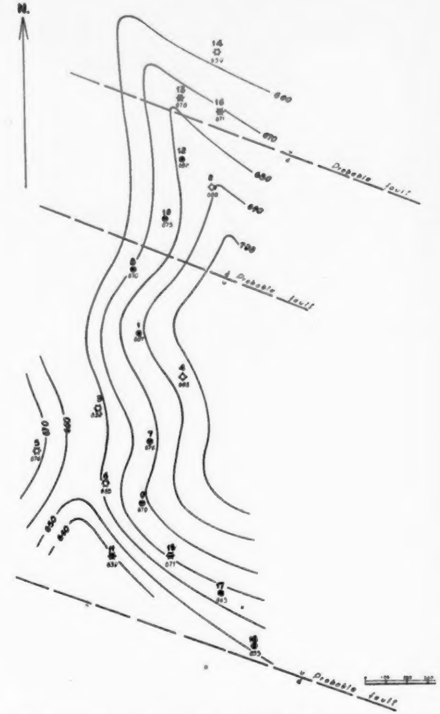


FIG. 11.—Isopach map of intervals between *Inoceramus* zone and Springhill formation. Scale: $\frac{1}{8}$ inch equals 100 meters.

lining the general area, the reflections were too obscure to be used for individual locations.

Up to the time of the completion of No. 13 (datum, −2,222 meters) it was considered that the oil-gas contact was approximately −2,230 meters, and that the oil-water contact was between −2,252 meters and −2,260 meters. Since the casing was set at −2,242 meters no trouble was expected. However, this well made oil with a very high gas-oil ratio. It was considered that the cement job might have been imperfect, but other wells in that part of the field developed similar troubles. Remedial work on No. 16 has resulted in a very fair well, though with high gas-oil ratios; but different fluid levels occur in that part of the field. Another factor which has thrown little light on the matter is the action of No. 11 (datum −2,203 meters and with a sand thickness of 10 meters) from which gas is being produced for the camp. After a few days of producing gas this well started to make about 50 barrels of oil per day, along with the gas. Many theories have been postulated to reconcile these phenomena but, to date, no pattern has been evolved which explains all the anomalous production.

COMPLETION PRACTICES

Completion practices have been variable. In many places the casing has been set above the sand and completed with a perforated liner. In others the casing has been set through the sand and perforated, and also completed with a liner. On the whole, the first practice has given the better results, but in the higher wells the latter practice was employed in order to shut off the gas.

CHARACTER AND QUANTITY OF OIL

The oil is high in gravity, about 42° Bé., and has a good gasoline and lubricating oil content. The gas is rich in gasoline.

Most of the oil wells have come in making about 25–35 barrels of oil per hour, through $\frac{1}{4}$-inch choke. Due to lack of storage facilities no lengthy tests have been made, the usual test varying from 24 to 48 hours. The lack of definite knowledge regarding the oil-gas and oil-water contacts, and the variability of the sand from one location to another preclude the possibility of making any accurate estimate of the reserves in that part of the field developed to date. In addition, there is no definitely known limit to either the north or south end of the field. At the south it has already overstepped the seismic picture, and at the north the principal problem is to secure an accurate structural picture. The quality of the sand is better in both directions.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 33, NO. 9 (SEPTEMBER, 1949), PP. 1590-1599, 5 FIGS.

BRAZILIAN OIL FIELDS AND OIL-SHALE RESERVES[1]

S. FRÓES ABREU[2]
Rio de Janeiro, Brazil

ABSTRACT

The largest area of oil possibilities in Brazil is the Amazon Valley. On Marajó Island, thick sediments have been proved recently by geophysics. The Maranhão Basin is being intensively investigated by the Conselho Nacional do Petroleo. In Sergipe, geophysical parties are working, and a test well was recently spudded. In São Paulo, six wells were drilled through Iratí beds, finding oil but not in commercial quantity. In Bahia, development of the Candeias and Don João fields is in progress; the total production of Bahia in 1948 reached 143,405 barrels and total reserves were estimated at 17.8 million barrels. Much interest is being devoted to the production of oil from oil shales in the Paraiba Valley and the Gondwana series of southern Brazil. In the Paraiba Valley, the oil shales can yield 20–25 gallons of oil per ton. The more uniform Iratí shales show enormous reserves, having an average yield of 23 gallons. Bituminous sandstones containing 8–14 per cent bitumen occur in São Paulo not far from the railroads. The sandstones were distilled for oil during the last war and now are mined for paving purposes.

Development of the oil-shale industry depends on economic factors determined by local conditions.

There are large areas in Brazil where oil might be found but due to lack of adequate investigation these areas remain completely unknown.

In the Amazon lowlands, in the western part bordering Perú, in the middle valley, and on the Marajó Island, the work already done indicates the possibility of finding oil. In Acre region, the observations of Pedro de Moura and Victor Oppenheim were the most detailed and showed the similarity of the formations with those of the petroliferous areas of eastern Perú. On Marajó Island the recent work of Geophysical Service Incorporated, of Dallas, for the Conselho Nacional do Petroleo, proved a thick sedimentary section which must be tested by a deep well.

The area to be studied in the Amazon Valley is enormous, covering 500,000 square miles. In the states of Maranhão, Piaui, and Goias, a large sedimentary basin is now under investigation by the C. N. P.

An area of more than 230,000 square miles is underlain by Paleozoic rocks with a thin cover of Mesozoic and Tertiary strata in the central and northern parts. The former work of A. Lisbôa and Moraes Rego has been completed by the recent investigations of F. B. Plummer, J. J. Brazil, D. F. Campbell, L. A. Almeida, S. O. Silva, F. A. Gomes, and others. According to J. J. Brazil the shales of the base of the Pedra de Fogo formation (Permian) may be considered a source bed of oil, as well as the Poti formation (Permo-Carboniferous).

D. F. Campbell, after a careful survey of the area in 1947, traced the probable limits of the part of the basin containing 2,500 feet of sediments; this area covers 125,000 square miles, chiefly in the state of Maranhão. In the Codó formation (Cretaceous) oil shales crop out near Codó, Barra do Corda, and Grajaú. These shales and the interbedded limestones give an odor of hydrocarbons when

[1] Read by title before the Association at St. Louis, March 17, 1949. Manuscript received, April 12, 1949.

[2] Instituto Nacional de Tecnologia.

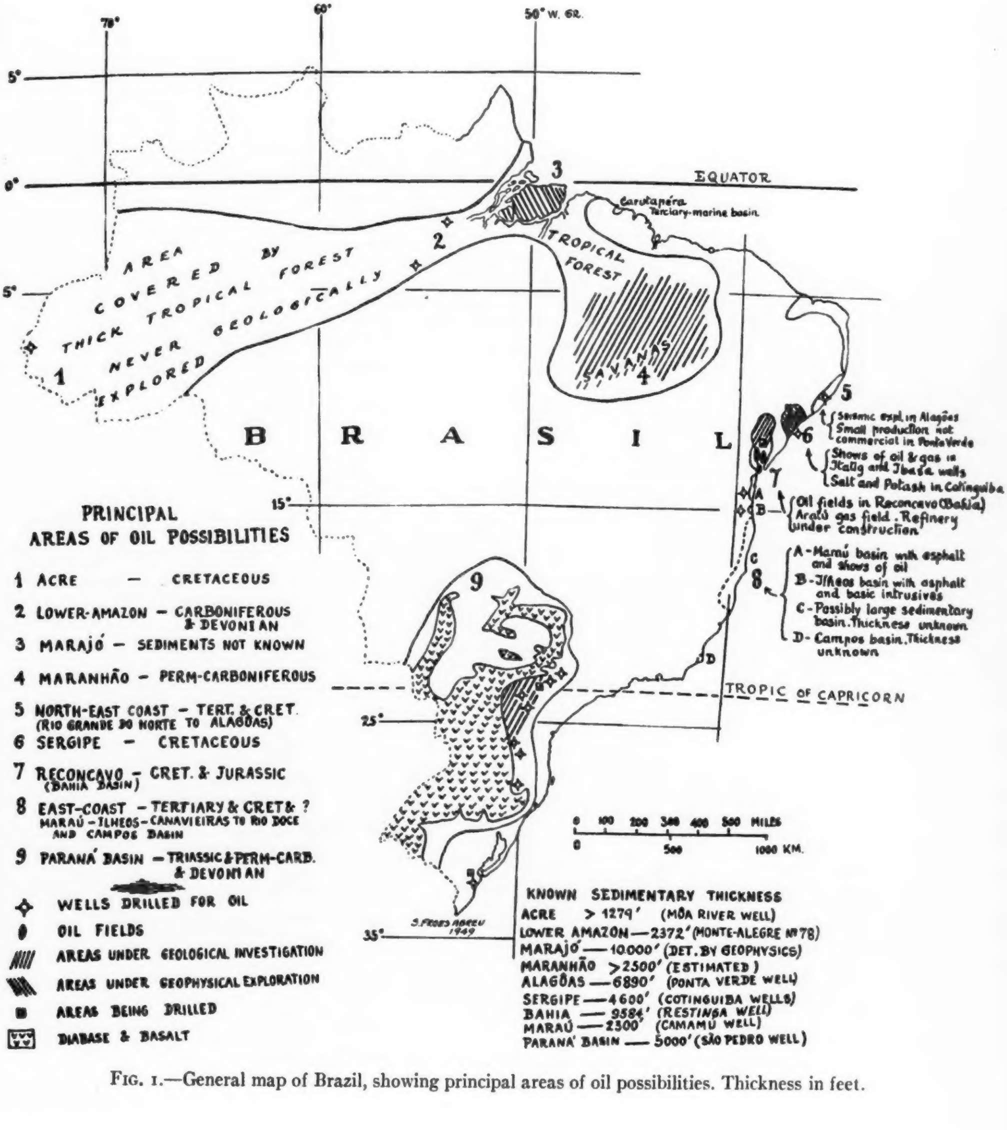


FIG. 1.—General map of Brazil, showing principal areas of oil possibilities. Thickness in feet.

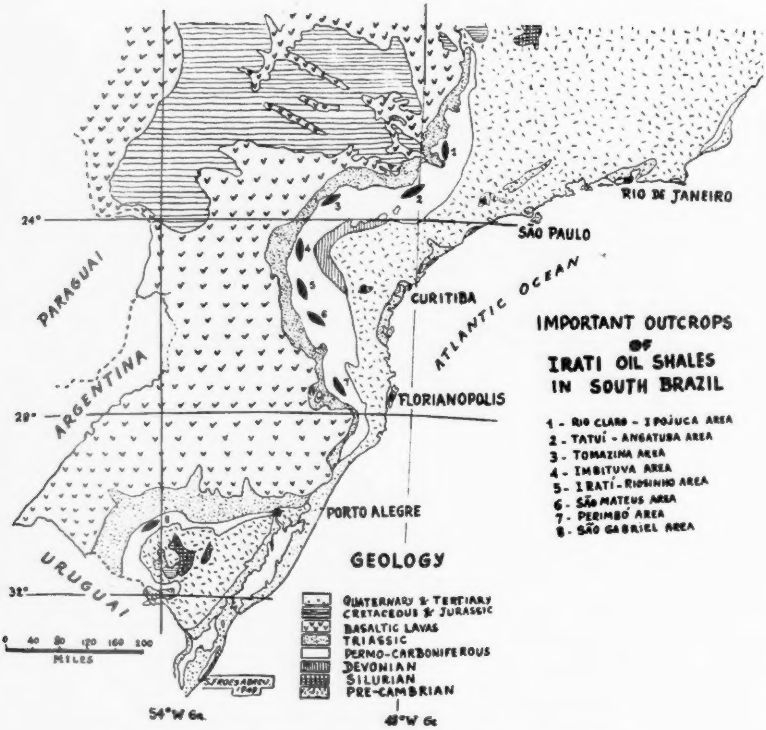


FIG. 2.—Important outcrops of Iratí oil shales in southern Brazil.

freshly broken, but this odor is due to gaseous matter originating from kerogen material.

According to Campbell, in the area studied in Maranhão there are no indications of truly large oil reserves, but there are possibilities of finding oil in commercial quantities, and he recommended more detailed investigations in the area, including a test well in the western part of Maranhão and another on the northeast.

Sergipe is another area under investigation by the C. N. P. A thick Cretaceous basin between the ocean and the crystalline rocks in the center of the state is being considered for oil possibilities. Eight wells drilled there by private interests a few years ago brought much attention to the area, due to the discovery of salt beds, anhydrite, and traces of oil. Several geological and geophysical parties have worked in Sergipe since 1946 and some structures have been outlined. One of them is being drilled by the Companhia Itatig. As a general feature, the Cretaceous of Sergipe is a homoclinal structure, dipping eastward; several faults and small folds may create conditions for trapping oil or gas.

The investigations in the Paraná Basin have not been intensive. One geophysical party worked in the center of the state of Paraná, making refraction and reflection profiles west of Ponta Grossa. In that area the sediments are not thick and the data agree with those measured in the Araquá well in São Paulo. No special structure has been outlined in Paraná by the geophysical work. In 1947 and 1948 a small company drilled six wells in São Paulo, in order to study the Iratí beds as a source of oil. Showings of black heavy oil have been noted, both in the fissures of the black shales of Estrada Nova and Iratí beds. In the limestone at the base of the Iratí, light oil was found in the small cracks and cavities, but due to lack of porosity and permeability no oil was produced.

BAHIA FIELDS

The only oil-producing area in Brazil is the Reconcavo in the state of Bahia. Oil was discovered in Lobato, in January, 1939, near a small seepage not far from Salvador; this encouraged the search for oil by the Brazilian Government. Lobato has been a poor field and now has only historical interest. Other fields have been discovered in the Reconcavo, not far from Lobato, and a very small amount of oil has been found in the Pitanga area, 30 miles north of Salvador.

The producing fields in Bahia are: Candeias with a proved reserve of 9.6 million barrels; Don João with 4.6 million, and Itaparica with 3.6 million; making 17.8 million barrels as the total reserves of the country. Aratú is mainly a gas field, with only small reserves of oil.

Candeias field.—This field was discovered in 1942 by geological work and confirmed by geophysics. It is 22 miles northwest of Salvador. The structure is an asymmetric anticline in the Cretaceous beds. The producing sandstone is 179 feet thick in the Santo Amaro formation. The oil is black paraffine-base, 26–30° A.P.I., and most of the wells must be pumped; the gas-oil ratio is 50–75 cubic feet per barrel. The average wells produce 175 barrels per day. Prior to 1948, 46 wells had been drilled in the Candeias area. In 1948, nine more wells were completed (8 producers, 1 dry), making a total of 8,779 meters of hole in this year.

Don João field.—This field was discovered in 1947; it is 5 miles west of Candeias and 20 miles from Salvador. The producing formation, the same as at Candeias, is shallow, ranging from 1,000 to 1,700 feet. The limits of this field have not yet been defined; only 12 wells have been drilled and the proved reserves are 4.6 million barrels. The Don João field is a faulted anticline, with several producing sandstones in the base of Santo Amaro formation and the Sergi sandstone of the Brotas formation. Oil is produced from 370 feet of sandstone which is not very porous and has low permeability.

Itaparica field.—This field, discovered in 1942, is in the northern part of Itaparica Island in the Todos os Santos Bay. The geology of Itaparica is similar to that of other areas of the Reconcavo and the producing beds are the sandstones of the Santo Amaro and Brotas formations. The oil and gas have accumulated in an anticline trending north and south.

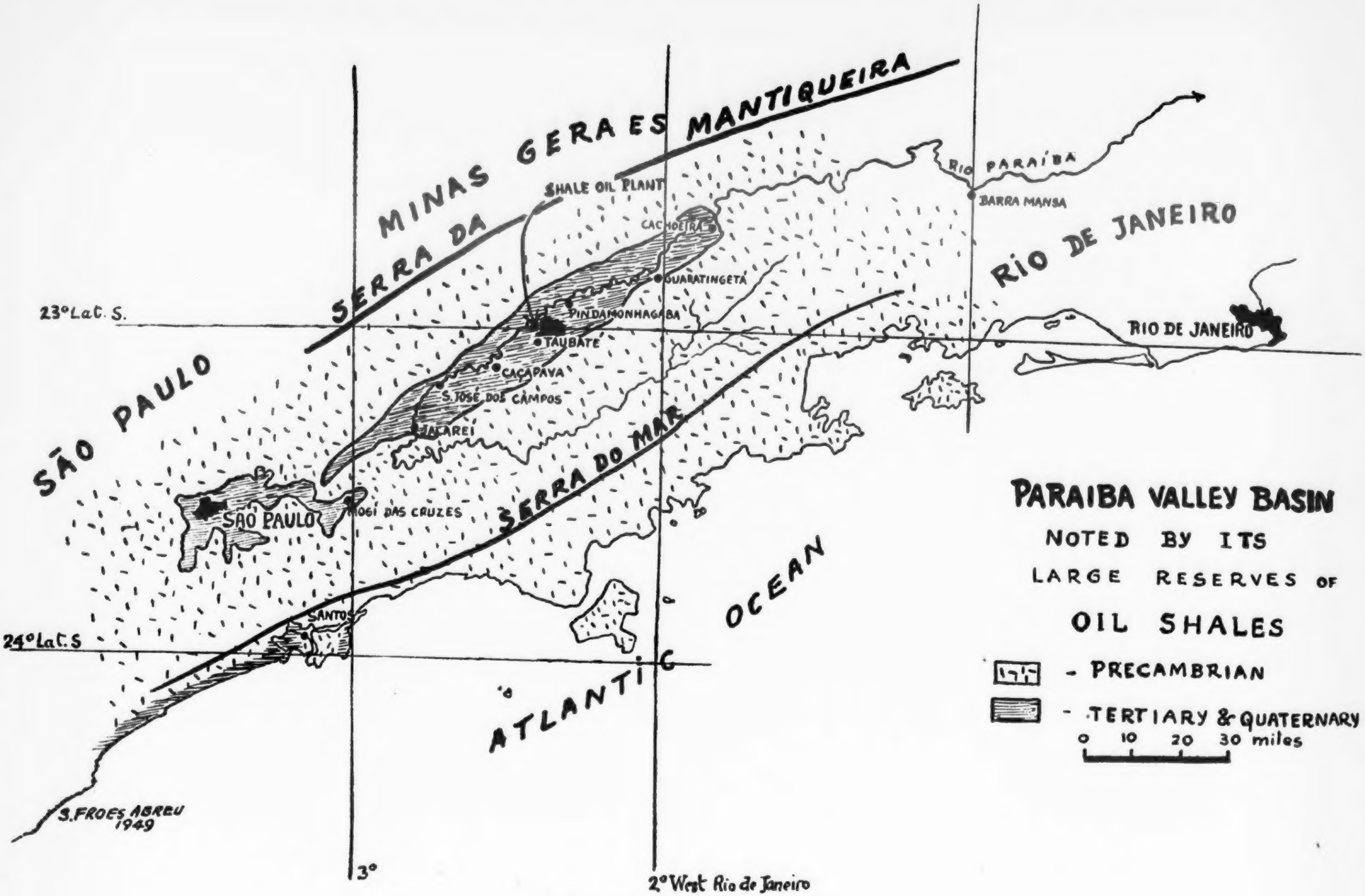


FIG. 3.—Oil-shale area of Paraiba Valley.

There are two producing zones; the upper consisting of fine to coarse sandstone, 36 feet thick; and in the Santo Amaro formation, the lower consisting of 42–260 feet of sandstone in the top of Brotas formation. The oil from the Itaparica field is black paraffine-base, 29° A.P.I., with high freezing point due to the high paraffine content. The main producing sand is at a depth of approximately 3,300 feet.

Aratú field.—This may be considered a gas field; it is 12 miles north of Salvador. Of 13 wells drilled, two are oil wells and 7 are gas wells. The producing formation, from 1,486 to 1,610 feet deep, consists of fine-grained sandstone giving light paraffine-base oil, 44° A.P.I. The gas-producing sand is from 1,866 to 2,330 feet deep and contains dry gas (95–97 per cent CH_4) at a pressure of 1,094 pounds per square inch. The crude from this field is distilled in a small topping plant and the products are consumed locally mostly by the C.N.P.

On January 1, 1949, there were in the Reconcavo 80 oil wells, 13 gas wells, and 54 dry holes. The yearly production of Reconcavo follows.

	(Barrels)
1940	2,089
1941	3,119
1942	32,631
1943	48,553
1944	57,533
1945	79,263
1946	66,889
1947	96,539
1948	143,405

The proved oil reserves on January 1, 1949, are 17.8 million barrels, and the gas reserves 42,916 million cubic feet.

A 2,500-barrel per day refinery is under construction in the Reconcavo in order to treat the crudes from Bahia fields.

OIL SHALES

Interest is being shown in the use of the Brazilian oil shales as a source of mineral oil. Though oil shales occur in several states, most of the deposits are not large enough to supply a synthetic fuel plant working on a commercial scale. The Brazilian bog-heads like those in Maraú and Jucú are very rich, producing samples yielding more than 50 gallons of oil per ton, but there are no reserves sufficient for a large-scale project.[3] It seems probable that commercial production of mineral oil from the Brazilian oil shales would be possible only in the Paraiba Valley (Tertiary) and parts of the Paraná Basin (Gondwana formation). In those two basins oil shales commonly occur, and at several places the thickness, the richness, or the easy mining conditions might permit economical use if the Government creates tax facilities and other special protective measures for the new industry.

[3] For details on the several oil-shale occurrences, see the recent paper of A. I. Oliveira, "Combustiveis Sinteticos," *Mineração e Metalurgia,*" Vol. 8, No. 76 (Rio de Janeiro, November–December, 1948). See also, "Rochas Oleigenas do Brazil," by S. Fróes Abreu, *Instituto Nacional de Tecnologia* (Rio de Janeiro, 1936).

FIG. 3.—Oil-shale area of Paraiba Valley.

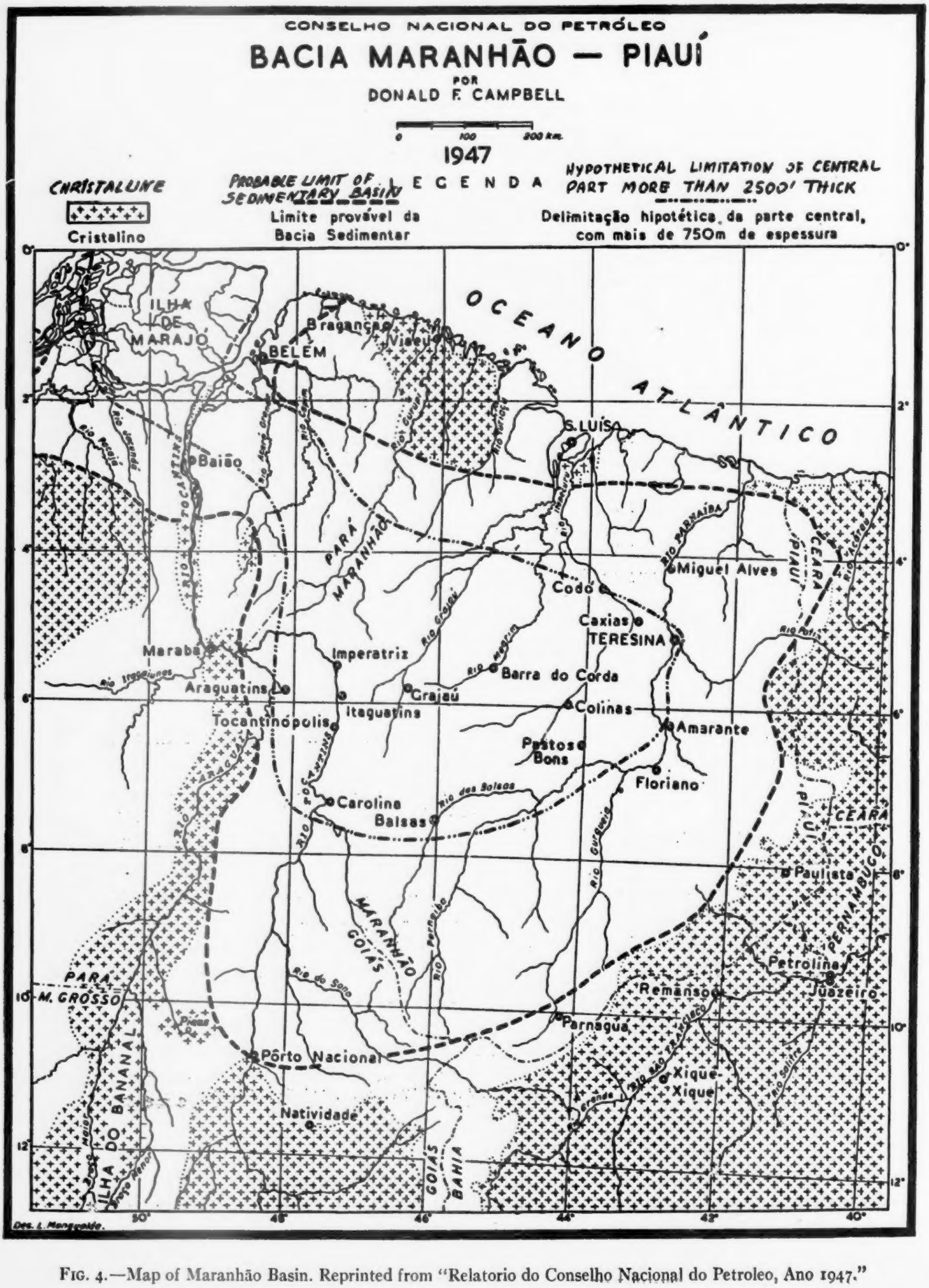


FIG. 4.—Map of Maranhão Basin. Reprinted from "Relatorio do Conselho Nacional do Petroleo, Ano 1947."

PARAIBA SHALES

In the Paraiba Valley, São Paulo, extensive oil-shale outcrops appear capable of supplying several plants located there. The main shale area, around Tremembé, is near the margin of the Paraiba River and is 100 miles from the city of São Paulo, 70 miles from Mogi das Cruzes, 114 miles from Barra Mansa, and 210 miles from Rio de Janeiro, all important industrial centers. The shales form important beds in an early Tertiary basin composed of clays and sands of lacustrine origin. The basin is between the Serra do Mar and Serra da Mantiqueira. The shales occur from the surface to a depth of many feet, in different layers of richness varying from 3 gallons of oil to 50 gallons in some thin layers of "papyraceous shale." In Taubaté, Tremembé, and Pindamonhangaba, several water wells have cut important layers of oil shale.

There are no surveys to permit calculation of the oil-shale reserves of this area, but it is a general opinion of those who know the region that the reserves are large and sufficient to maintain an important oil-shale industry. The most important factor to be verified is the quantity of oil which can be recovered from a ton of run-of-mine shale, without selection of the material. Numerous analyses show an oil content of 3–50 gallons per ton, but from all analyses available, 55 per cent show less than 20 gallons, which in our opinion can not be worked economically.

For a large-scale project it would be necessary to select an area of better material, offering at the same time good mining conditions. An unfavorable condition in these deposits is the high moisture content of the rock, amounting in some layers to 40 per cent. The heat consumption to evaporate all this water offsets the advantage of the favorable location of the deposits. The oil from the Paraiba shales is high in paraffine and, as all shale oils, contains a high proportion of unsaturated hydrocarbons. During the war some oil was produced in the old plant at Taubaté; it gave a product of 33° A.P.I. which was used as fuel oil.

GONDWANA SHALES

The Gondwana rocks consist of Permo-Carboniferous beds which crop out from São Paulo to Rio Grande do Sul, a distance of more than 900 miles. They include in several places outcrops of the Iratí beds which contain black shales and dark dolomitic limestones. The Iratí beds, 100–200 feet thick, give an odor of petroleum and when distilled produce substantial quantities of oil. The black shales are more typical of the upper part of the Iratí group, whereas the limestones occur in the middle and lower parts.

The Iratí oil shale commonly produces 23 gallons of oil per ton; the oil is black, sulphurous, 19° A.P.I., and high in unsaturated hydrocarbons. Attempts to produce oil from these shales have been made in São Paulo, Paraná, and Rio Grande do Sul, but all resulted in failures. The small plants erected in Angatuba, São Mateus, and São Gabriel were primitive and had no possibility of success. In Paraná, Professor L. Weber of the Chemical Division of the Instituto de Biologia e Pesquisas Tecnologicas, made accurate studies of the industrialization of the Iratí shale in Paraná.

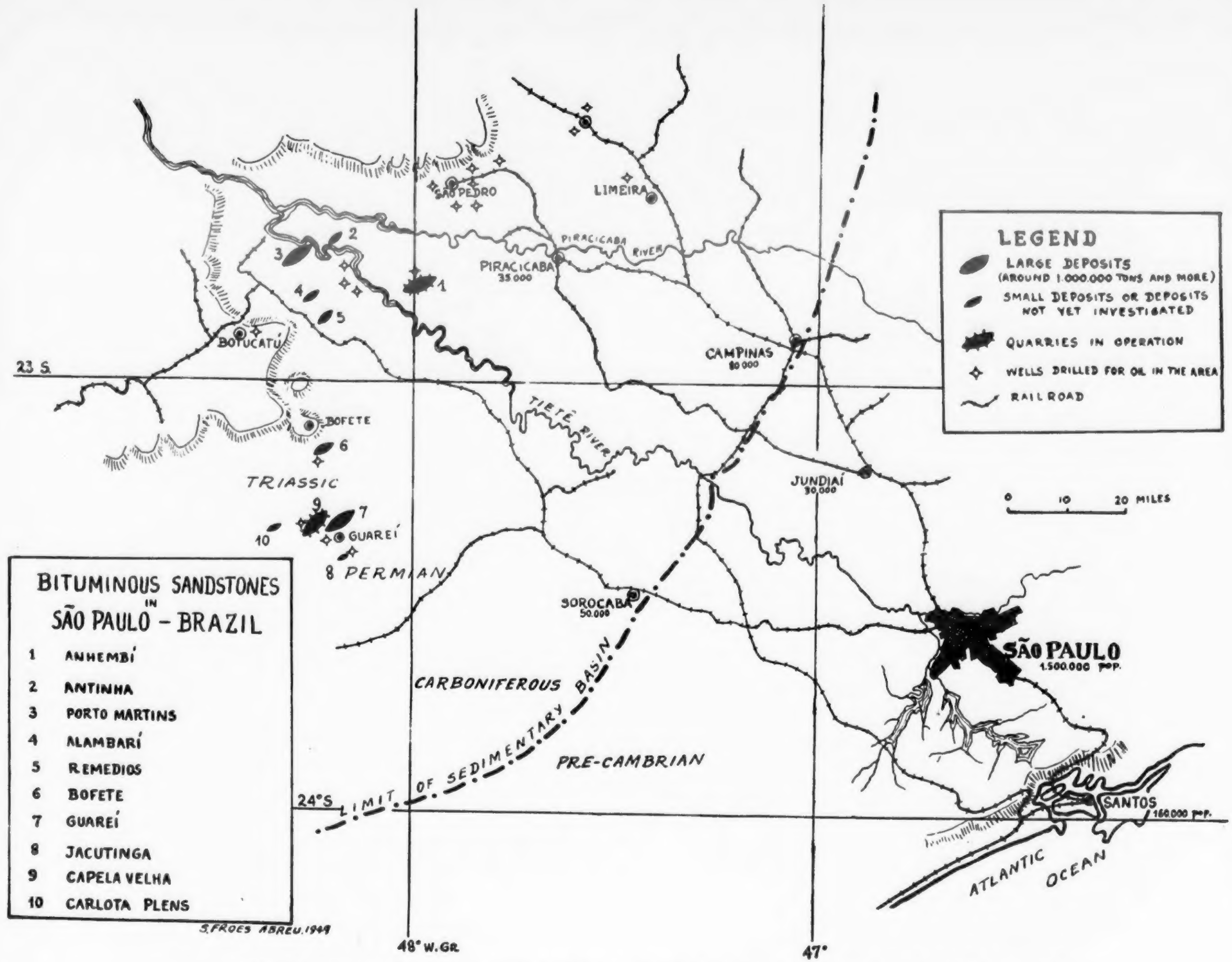


FIG. 5.—Map showing location of bituminous sandstones and principal towns (with population), São Paulo, Brazil.

The tonnage of black shales in the Iratí formation is large and represents the largest reserves of organic shales known in Brazil. In many places the local conditions permit the mining of the shale at very low cost, and in these places, if special protection were granted by the Government, a synthetic fuel industry might be established.

TRIASSIC SANDSTONES

In São Paulo several occurrences of bituminous sandstones containing 8–14 per cent bitumen are known. The deposits form impregnated layers in the Piramboia beds near diabase dikes and the bitumen is the result of evaporation of the lighter fractions of oil derived from the Iratí limestone. Two of these deposits are already being worked as asphalt for paving roads, but ten more have not yet been explored. During the last war the Companhia Itatig distilled these bituminous sandstones to produce oil. The sandstone was distilled in a small plant in rotary retorts and gave about 16 gallons of oil per ton. In a skimming plant the company obtained gasoline and fuel oil which were sold in the local market at high prices due to the shortage of imported fuel. According to the type of the retort, the oil obtained had different characteristics, with different proportions of gasoline. The gasoline was consumed immediately in the cars and trucks with much success due to its high octane number. Production of oil was 40 barrels a day in the more active period. The known reserves of bituminous sandstones in São Paulo are estimated as 5–6 million tons and are not large enough for a broad program of oil production by distillation.

CONCLUSION

On the basis of present knowledge of the oil-shale and bituminous deposits in Brazil, only the Iratí and Paraiba Valley shales may be considered in a program for synthetic fuels.

As the proved reserves of petroleum and natural gas are small, attention is being turned to the possibility of using the oil shales. The first step in such a program must be a detailed survey of the areas where the material producing a satisfactory quantity of oil can be mined. The shale-oil industry can not compete with the imported natural petroleum unless the cost of processing the shale containing 25 gallons of oil can be held to $1.20 (U.S.) per ton so as to produce oil at $2.00 (U.S.) per barrel. The raw shale oil would have to be treated as sour petroleum to give satisfactory products.

The possibility of operating in Brazil at such low costs is doubtful, even with the most modern equipment.

The possibility of supplying our growing demand for petroleum products with shale oils is not bright, due to the high cost of labor, low grade of the shales, and severe taxation. Only through Government protection, and for special reasons and purposes, can the oil shale industry be established in Brazil. In view of the uncertainty about the development of a domestic supply of petroleum, now prevailing, it is advisable also to carry on investigations looking toward the possible utilization of the more favorable shale deposits.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 33, NO. 9 (SEPTEMBER, 1949), PP. 1600-1612, 5 FIGS., 1 TABLE

ACTIVE-SURFACE CATALYSTS IN FORMATION OF PETROLEUM—II[1]

BENJAMIN T. BROOKS[2]
New York, N. Y.

ABSTRACT

In a previous paper some evidence was presented to account for the changes in the composition of petroleums with age and depth, by the action of active-surface catalysts. In 1934, D. C. Barton published graphs based on United States Bureau of Mines analyses of petroleums from Gulf Coast fields. Barton's graphs for the Gulf Coast Miocene, Oligocene, and Eocene oils indicated progressive change in composition with age and depth, the older and deeper oils having larger percentages of light constituents and less heavy residue. Barton's graphs did not show points corresponding with the composition of the oils considered in preparing the graphs. In the present paper, analyses of Gulf Coast oils are plotted, including the composition of oils discovered since Barton's work in 1934, together with many produced at depths not yet reached at that time.

The results shown in the present paper disclose that the regularity in change with age and depth is not as uniform as was indicated by Barton's graphs and, although many irregularities are evident, the average results show a general tendency which is in agreement with Barton's conclusions.

It is evident from the composition of crude petroleums generally that there is little or no regular or uniform relationship in age and depth and composition, and that such a relationship is only qualitatively true of the composition of oils in fields in a relatively restricted area, such as the Gulf Coast fields, which were the basis of studies by D. C. Barton (1). The extent to which there is a relation in composition and age and depth is better shown on the graphs here presented than by Barton's figures which did not show plot points. Thus the petroleum from the Raccoon Bend field, produced from the Jackson formation (Eocene) at about 3,200 feet, contains slightly more gasoline than the oil from the Segno field, produced from the Wilcox formation (Eocene) at about 8,200 feet. Similarly oils of substantially the same age and depth commonly vary considerably in composition. Thus the oil produced in the West Conroe field from the Cockfield formation at 4,200 feet contains about 17 per cent gasoline as compared with 33 per cent gasoline from the Cockfield formation at 4,152–4,207 feet in the Livingston field.

In plotting the results presented here, analyses which evidently were from so-called distillate wells were not included since the composition of such oils obviously does not represent the composition of the entire crude oil. Thus the oil reported from the Aldine field, Yegua formation, at 7,186–7,791 feet, is to be regarded as a distillate rather than the crude occurring in this formation at this point. High gas-oil ratios and light crudes resulting in distillate wells are generally found in the Gulf Coast fields at depths of 5,000–10,000 feet. Heavy oils with low gas-oil ratios rarely occur at these depths, but are observed in some wells.

When all of the crude oils in the Gulf Coast classification were plotted, there were several which were somewhat out of line in composition, and the plotted

[1] Manuscript received, May 4, 1949.

[2] Consulting chemist, 405 Lexington Avenue.

results would have been consistent with the others of the Texas Gulf Coast fields if the producing formations had been 1,500–2,000 feet deeper. Practically all of the fields in this category were found in the counties near Corpus Christi. The wells in this area which are not shown in the plots include the Kelsey field in Jim Hogg County, the Tom Graham and Captain Lucy fields in Jim Wells County, the Luby field in Nueces County, the McFaddin and Keeran fields in Victoria County, the Greta, LaRosa, and Tom O'Connor fields in Refugio County, the Sun field in Starr County, and the Plymouth field in San Patricio County, all of which produce from the Oligocene. Of the fields in this area producing from Eocene formations, the following were not plotted: the Schott and Laurel fields in Webb County, the Dirks, West Tuleta, and Pettus fields in Bee County, and the McNeil field in Live Oak County. These represent a slight anomaly for this area as compared with the other Gulf Coast fields.

This anomaly might not actually be an anomaly if bottom-hole temperatures instead of depth were used as the basis of plotting the results. It was pointed out in the previous paper (3) that depth is probably not the proper criterion to be employed in making these comparisons, and reasons were given for the belief that pressures are not a factor in affecting change in composition of petroleums with age and depth. Although temperatures alone, such as encountered as bottom-hole temperatures in the Gulf Coast fields, can not be regarded as sufficient to affect chemical changes in the composition of these crudes, it was suggested that, even at these comparatively low temperatures, the apparent changes in composition might well be explained by the action of the active-surface minerals with which the crude oils have been in contact through long periods of time. If this be true, the maximum or bottom-hole temperatures are a better criterion than depth.

E. A. Nichols (11) has shown that in the Gulf Coast area the temperature gradients vary from 1.6 to 2.2°F. per 100 feet. Such differences in temperature gradients may be sufficient to account for some of the anomalies in composition which are indicated in Figures 1–3. The writer has been unable to ascertain the bottom-hole temperatures of all of the fields, data for which are herein shown.

The widest differences in temperature gradients noted by Nichols, with an average surface temperature of 74°F., would give bottom-hole temperatures of 174°F. and 206°F. at 6,000 feet. If other conditions were the same, any chemical change which could occur very slowly at 174°F. would occur at a rate three to four times as great at 206°F. It is recognized that petroleum-producing formations only attain their maximum bottom-hole temperatures very slowly as the insulating, overlying, sedimentary blanket builds up in thickness. Nevertheless, temperature differences of 30°F. are enough to account for differences in the composition of petroleums in the same formation. Sufficient statistical data on bottom-hole temperatures are not at present available to the writer to prove the point, but bottom-hole temperatures, in the Gulf Coast fields, are believed to be a better criterion than depth, in the correlations considered here.

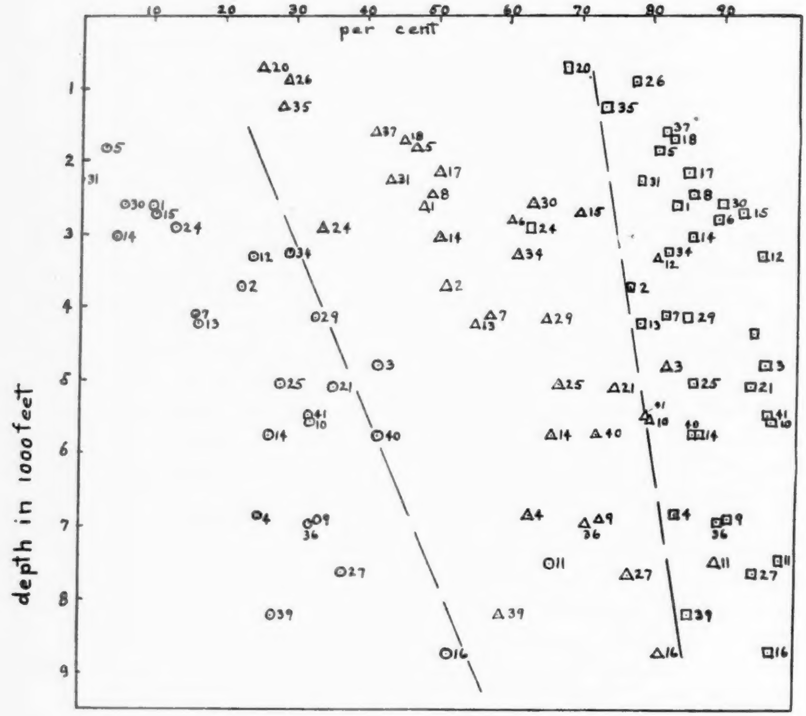


FIG. 1.—Texas Eocene.

TEXAS GULF COAST, EOCENE(7, 9, 10)

(Key to Figure I)

No.	*Field*	*Formation*	*Deph in Feet*	*No.*	*Field*	*Formation*	*Depth in Feet*
17	Albereas	Jackson	2,125–2,160	27	Joe's Lake	Wilcox, Eocene	7,665–7,695
11	Aldine	Yegua	7,186–7,791	29	Livingston	Cockfield	4,152–4,207
18	Aviators	Jackson	1,740	30	Loma Novia	Jackson	2,566–2,587
3	Benavides	Jackson	4,800	6	Loma Novia	Loma Novia	2,800–2,820
19	Caesar	Cockfield	3,055–3,062	31	Lopez	Jackson	2,244–2,254
20	Callihan	Jackson ?	704–725	15	O'Hern	Cockfield	2,700
12	Conoco Driscoll	Hockley and Government Wells	3,250	34	Raccoon Bend	Jackson	3,208
				7	Raccoon Bend	Cockfield	3,991–4,130
13	Conroe, West	Cockfield	4,200	35	Randado	Jackson	1,258–1,288
21	Conroe	Cockfield	5,067–5,152	36	Satsuma	Cockfield	6,825–6,835
4	Fairbanks	Yegua	6,845	37	Schott	Jackson	1,607
14	Fostoria	Cockfield	5,790	39	Segno	Wilcox, Eocene	8,008–8,400
5	Government Wells	Lower Cole	1,749–1,815	8	Seven Sisters	Government Wells	2,450–2,486
1	Hoffman	Hockley	2,650–2,875	16	Sheridan	Wilcox, Eocene	8,700
24	Hull	Jackson	2,860–3,023	9	Silsbee	Cockfield	6,901–6,915
2	Hull	Yegua	3,755	40	South Sweden	Cockfield	5,871–5,887
25	Humble	Jackson	4,866–5,316	10	Tomball	Cockfield	5,335–5,544
26	Jacobs	Cockfield	894–899	41	Tomball	Cockfield	5,535–5,544

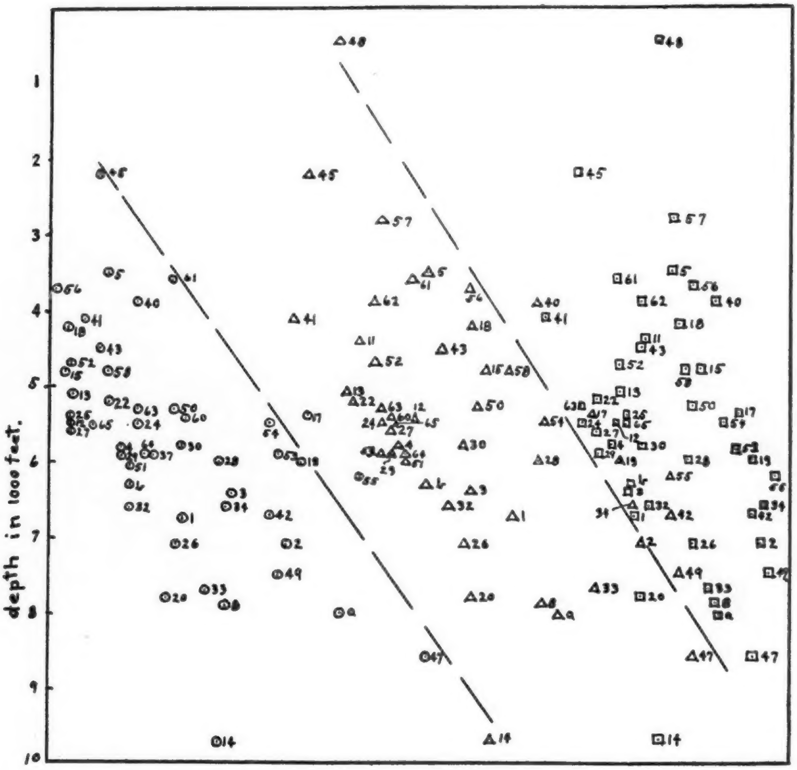


FIG. 2.—Texas Oligocene.

TEXAS GULF COAST, OLIGOCENE (7, 9, 10)
(Key to Figure 2)

No.	*Field*	*Formation*	*Depth in Feet*	*No.*	*Field*	*Formation*	*Depth in Feet*
1	Amelia	Frio	6,770	51	Nome	Marginulina	6,010–6,060
26	Anahuac	Frio	7,100	14	Old Ocean	Frio	9,690
2	Aransas	Frio	7,113	52	Pickett Ridge	Frio	4,669–4,710
38	Aransas	Frio	6,151–6,560	34	Premont, East	Lower Frio	6,590–6,620
3	Barbers Hill	Oligocene	6,400	15	Placedo	Oligocene	4,773
27	Beaumont, West	Marginulina	5,400	53	Placedo	Frio	5,943–5,953
40	Clara Driscoll	Catahoula	3,888–3,958	54	Plymouth	Frio	5,501–5,512
28	Cedar Point	Frio	5,922–6,120	55	Port Lavaca	Oligocene	6,236–6,238
4	Clear Lake	Frio	5,800	56	Refugio	Catahoula	3,675–3,686
29	Clear Lake	Frio	5,850	17	Refugio	Oligocene	5,362
(a)	Dickinson	Frio	8,010–8,060	57	Sam Fordyce	Frio	2,761–2,763
41	Esperson	Oligocene	4,090–4,124	18	Saxet	Upper Oligocene	4,200
42	Flour Bluff	Marginulina	6,633–6,696	58	Saxet	Middle Oligocene	4,842–4,847
43	Goose Creek	Oligocene	4,448–4,468	19	Seeligson	Frio	6,000
5	Greta	Oligocene	3,505	60	Spindle Top	Upper Oligocene	5,365–5,417
30	Hastings	Frio	5,602–6,080	20	Stowell Winnie	Frio	7,800
45	Humble	Oligocene	2,185–2,206	61	Sugarland	Frio	3,600
47	La Belle	Frio	8,622	62	Taft	Middle Oligocene	3,975–3,980
32	Lockridge	Frio	6,300	22	Thompson	Frio	5,137
48	Los Almos	Frio	445–465	63	West Columbia	Marginulina	5,280–5,340
33	Lovells Lake	Upper Frio	7,716–7,719	24	West Columbia	Frio	5,500
8	Lovells Lake	Frio	7,800	64	West Columbia	Frio	5,900–5,913
13	Manvel	Oligocene	5,107	25	Withers	Frio	5,400
49	Mercedes	Frio	7,477–7,493	65	Withers	Marginulina	5,539–5,564
50	Midway	Middle Oligocene	5,281–5,407				

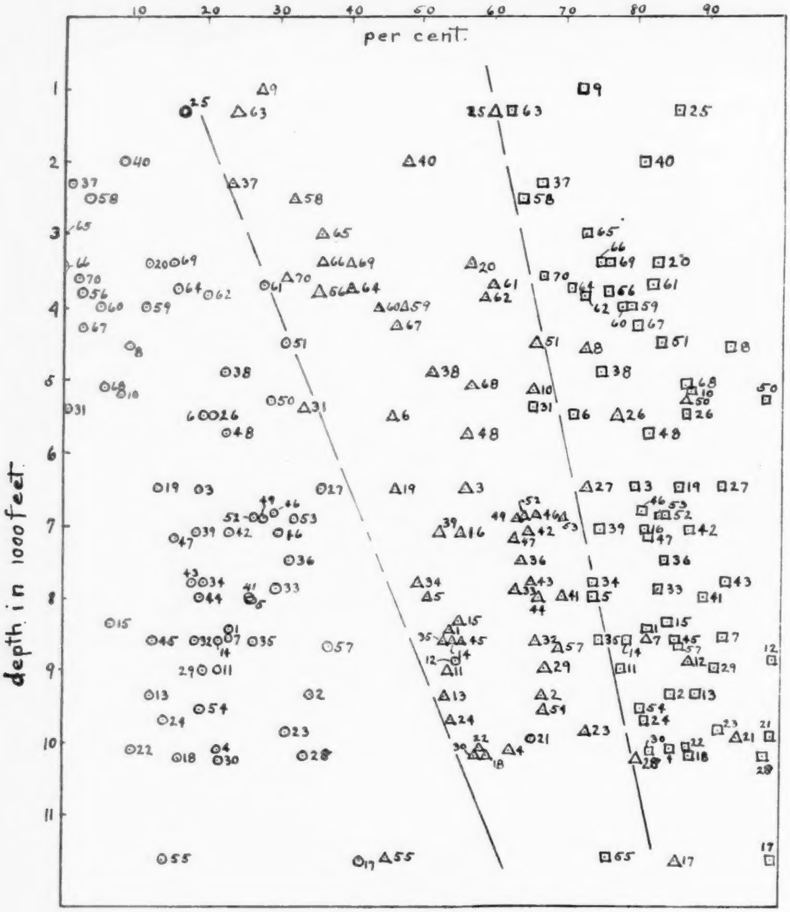


Fig. 3.—Louisiana Miocene.

Louisiana, Miocene (6, 8, 10)

(Key to Figure 3)

No.	*Field*	*Depth in Feet*
1	Barataria	8,200–8,700
2	Bastian Bay	9,352–9,362
3	Bayou Couba	6,536–6,542
4	Bayou Sale	10,063–10,098
5	Bay St. Elaine	6,000–10,000
6	Bay St. Elaine	5,000–6,000
7	Big Lake	8,571–8,586
8	Cameron Meadows	4,600
9	Charenton	900–1,100
10	Creole	5,160
11	Delta Farms	9,010–9,050
12	Erath	8,700–1,165 (8,900)
13	Gibson & Gibson	9,190–9,500
14	Grand Bay	7,100–10,000 (8,600)
15	Grand Lake	8,365–8,392
16	Hackberry, East	7,088–7,097
17	Hayes	11,646–11,670
18	Horeshoe Bayou	10,180–10,280
19	Jeanerette	6,400–6,600
20	Jefferson Island	3,070–3,780
?21	Lake Arthur	9,945–9,972
22	Lake DeCade	10,214–10,219
23	Lake Long	9,356–10,419 (9,850)
24	Lake Salvador	9,670–9,708
25	Lake Veret	1,300
26	Lockport	5,500
27	Lockport	6,504–6,554
28	Mermenteau	10,175–10,222
29	Napoleonville	9,024–9,050
30	Paradis	10,076–10,415
31	Perkins	5,367–5,380
32	Quarantine Bay	8,618–8,630
33	Roanoke	7,935–7,945
34	St. Gabriel	7,760–7,780
35	St. Gabriel	8,600–8,615
36	Stella	7,500
37	Vinton	2,276–2,400
38	Vinton	4,908–4,914
39	West Bay	6,260–8,000 (7,100)
40	West Cote Blanch Bay	2,000
41	Woodlawn	8,036–8,046
42	Bayou Mallet	6,997–7,208
43	Bosco	7,798–7,850
44	Bosco	8,060–8,085
45	Bosco	8,585–8,606
46	Caillou Island	6,844–6,862
47	Charenten	7,180–7,194
?48	Darrow	5,760–5,781
49	Dog Lake	6,871–6,894
50	Four Isle	5,501–5,569
51	Garden Island Bay	4,480–4,544
52	Harag	6,920–6,952
53	Iowa	6,895–6,912
54	Lafitte	9,558–9,572
55	Lirette	11,615
?56	New Iberia	3,790–3,840
57	Roanoke	8,671–8,694
58	Vinton	2,525–2,570
59	Darrow	4,008
60	Geydan	
61	Lake Barre	3,670–3,703
62	Lake Barre	3,800
63	Lake Pelto	1,300
64	Leesville	3,700
65	Lockport	3,000
66	Lockport	3,300
67	Lockport	4,300
68	Lockport	5,100
69	Port Barre	3,400
?70	Port Barre	3,600

In the Gulf Coast area of Louisiana the temperature gradients are generally less, or 1.2–1.4°F. per 100 feet. It is recognized that state boundaries have nothing to do with local geology, but the lower temperature gradients in the Louisiana Gulf Coast area may justify plotting this area separately from the Texas Gulf Coast. The number of oils producing from the Miocene in Texas was considered hardly sufficient to be significant when plotted, but the number of fields in Louisiana producing from Miocene formations is large, and is shown in Figure 3. Here again, there is no real regularity, but only a general tendency with many anomalies. These anomalies are apparent from an inspection of the figures. Thus the crude oil produced in the Lirette field from Miocene formations at 11,600 feet contains only about 14 per cent gasoline and about 24 per cent heavy residuum. Similarly, the crude produced in the Grant Lake field from the Miocene at 8,365–8,392 feet contains only about 6.5 feet gasoline.

In Figure 1, representing the composition of oils from the Texas Oligocene, the percentages of gasoline and naphtha are represented by the small circles at the left of the first inclined line; the distance from the small circles to the small triangles represents the percentage of kerosene and gas oil; the distance from the triangles to the squares represents the percentage of lubricating oil distillates; and the distance from the squares to the right-hand margin represents the percentage of heavy residue. The data used in making Figures 1, 2, and 3 were taken from publications of the United States Bureau of Mines (6–10).

As pointed out in the previous paper (3), there are great differences in the catalytic activity of different formations as measured experimentally, by the ability of such material to affect polymerization of reactive, unsaturated hydrocarbons. It is obviously impossible to test experimentally, at the relatively low temperatures in question, the catalytic activity of the minerals found in the producing formations with respect to their ability to affect changes in composition other than polymerizations. It was pointed out, however, that in general, active cracking catalysts are also good polymerizing agents, and it is particularly significant that Gayer (5) did produce experimentally a large number of saturated and unsaturated hydrocarbons from propylene by various catalysts at temperatures substantially below those at which cracking occurs in the absence of catalysts. Some of Gayer's catalysts were 25 times as active in affecting these changes as the best fuller's earth. Polymerizing activity, particularly in Gayer's results, is believed to be a good indication or index of catalytic activity resulting in hydrocarbon splitting, disproportionation, and the formation of a large variety of simple hydrocarbons from more complex ones. This was more fully discussed in the previous paper.

OILS FROM CRETACEOUS FORMATIONS

When the compositions of crude petroleums of Cretaceous age or older are examined, there is no evidence of any correlation in composition and age and depth as indicated in the Gulf Coast Eocene, Oligocene, and Miocene oils. In many

places, Cretaceous and older oils occur at relatively shallow depths for obvious geological reasons, and their present depth and bottom-hole temperatures may be much less than before the removal of overlying formations by erosion. As indicated by Barton (1), the Gulf Coast area is probably unique among oil-producing provinces in the United States in which the correlations studied by him and discussed here can reasonably be made. It appears probable that oils produced from Cretaceous or older formations are old enough to have resulted in the formation of what might be called well developed crudes, containing 25 per cent or more of gasoline, when in contact with formations of average catalytic activity. Unlike the Gulf Coast fields, some Cretaceous formations in central Texas and in the East Texas basin commonly show a high content of gasoline even though produced at what are now very shallow depths. Thus the Minerva field, producing from the Navarro sand at 750 feet, yields a crude oil containing 32.5 per cent gasoline. The East Texas field, producing from the Woodbine sand at 3,536–3,702 feet, yields crude containing 35.8–37.1 per cent gasoline.

An interesting anomaly is the oil produced in the Van field from the shallow Nacatoch (Cretaceous) formation at 1,251–1,277 feet, which yields an oil containing no gasoline or naphtha, and 53.0 per cent heavy residue. It has frequently been suggested that heavy oils produced from such relatively shallow depths have lost their light constituents by some sort of evaporation or diffusion process. However, the oil from the Minerva field produced from 750 feet and containing 32.5 per cent gasoline and naphtha, and many similar results which can be cited, seems to disprove such a theory.

If it be assumed, as has been suggested, that the catalytic activity of the reservoir formations has been a factor in transforming bitumens into lighter oils containing substantial percentages of gasoline and naphtha and smaller percentages of heavy residue, then in view of the marked differences in catalytic activity of different minerals which are in contact with the oil, it is to be expected that oils of the same age and depth may show substantial differences in composition. There are abundant examples illustrative of such differences in oil composition. It should not be necessary to examine for catalytic activity cores from all of the producing formations represented in the plotted figures presented here, but it is realized that some direct evidence of this kind would be desirable. It was pointed out in the previous paper that the apparent anomalies should be carefully considered. It was noted that some heavy crudes of Cretaceous or older age are known containing little or no gasoline and naphtha, and a high percentage of heavy residue. Many of these heavy oils are produced from limestone reservoirs which, in reasonably pure limestones and dolomites, have no catalytic action as measured by polymerization. Limestones could not be expected to have catalytic active surfaces owing to selective adsorption of naphthenic acids. Clays, shales, and formations containing a substantial percentage of clay material, do show catalytic action, but it is possible for clean, coarse sand formations to have no catalytic action at all.

It should be of great interest to test experimentally for catalytic activity some of the formations which show very abnormal oils, either very light or very heavy crudes. Thus the Athabaska tar sands are Cretaceous in age and the heavy bitumen in these sands contains no light oils. Such test cases should indicate clearly whether progressive changes in oil composition are due to the catalytic activity of minerals with which the oil or bitumens are in contact. The Athabaska tar sand has been examined by extracting the bitumen with hot benzene. The extracted sand consists of rounded quartz sand, free from fines or clay (Fig. 4). It showed no polymerizing activity when tested with readily polymerizable hydrocarbons such as pinene and trimethyl ethylene. As in testing fuller's earth for polymerizing activity, the sand was partly dehydrated by heating to approximately 300°F. The fact that the sand is unconsolidated or lithified by cementing material indicates that the bitumen filled the sand very early in its history, which would be consistent with the supposition that the heavy oil has been preserved unchanged in contact with the coarse non-catalytic quartz sand.

FACTORS PROBABLY AFFECTING OIL FORMATION AND COMPOSITION

Petroleums differ so widely in composition that some who have inquired into the matter of petroleum origin have despaired of accounting for these differences. It is not suggested here that we now know all of the answers, but many of the factors are already well established. It is believed advisable to mention them briefly since, in discussing the particular subject of this and the preceding paper, the criticism may be made that some of the factors have been left out. The following influences probably affect petroleum composition.

1. *Selective adsorption and separation of light oils from heavier constituents during migration.*—This effect is well established, demonstrated experimentally, and is generally believed to account for crude oils of very high gasoline content many of which are substantially free from asphalt or heavy residues.

2. *Age.*—The youngest petroleums produced in the United States are those from the Pliocene formations in California. The minimum time required to form oil which is sufficiently fluid to flow and migrate, forming accumulations which can be drilled and produced as oil, is not known. The history of the chemical changes in the composition of organic débris, such as found in contemporary sediments and heavy asphaltic material, and resulting finally in typical petroleum containing light hydrocarbons, is not known, but is certainly discoverable. The time factor involved in such changes probably varies greatly and may be dependent on the nature of the mineral matter with which the organic material is in contact, together with its temperature history.

3. *Temperature and depth.*—For reasons pointed out in the previous paper, the temperatures observed as bottom-hole temperatures in oil-producing formations are alone not sufficient to produce petroleums from the original organic débris, or to transform the heavy asphaltic material, which is probably formed in early stages, to typical petroleum. However, if such chemical changes are due

FIG. 4.—Photomicrograph of extracted Athabaska tar sand. Magnification 25 diameters. (Foster D. Snell Laboratories.)

to catalytic action of the mineral matter in contact with the oil, then the temperature gradients in oil fields are important and bottom-hole temperatures are a better criterion than depth. It is obvious that the temperature history in many fields can never be known, for example, in fields now at shallow depths which in earlier time were deeper and subjected to temperatures higher than those now observed in these formations. In the Gulf Coast fields, studied by Barton and discussed here, the observed bottom-hole temperatures are probably the maximum for the entire history of these deposits.

4. *Pressure.*—It is believed that this has not been a factor in the formation of oils or in producing chemical changes in petroleums for reasons discussed in the previous article.

5. *Differences in chemical composition of organic dêbris deposited in original source sediments.*—It is believed that present knowledge about this factor may be summarized as follows. The original source material of petroleums, probably without exception, certainly with few exceptions, was deposited in marine sediments. The source material was not cellulose, lignin, and resins which result from the vegetation in swamps or bogs. These conditions are generally believed to have resulted in peat (Recent), and various types of coal. The original source material of petroleum obviously varied in composition with variations in the character of the ocean plankton, algae, and other sources of the original organic material. However, the problem is rather to account for the formation of typical petroleums from any such original organic source material. The precise nature of such original organic matter can never be known, but may be assumed to be in general like the organic matter found in contemporary marine sediments such as those investigated by Parker D. Trask (14). The chlorophyll porphyrin in many petroleums proves the presence of algae as well as rapid sedimentation to preserve such material under anaerobic conditions. The speculation that differences in the composition of petroleums can be attributed to different original organic source material produced by different environments is entirely without any supporting facts or evidence, and is not susceptible of proof.

6. *Bacterial action.*—Bacterial action may have been an important factor in early history of the deposits by bacterial degradation of the organic material as first laid down and buried in the sediments. There is no evidence that bacterial action can change asphalt or heavy oils into lighter hydrocarbons, or even form asphaltic or heavy bitumens from organic matter, such as Trask found in Recent sediments.

ZoBell (15) has called attention to the fact that many species of bacteria produce hydrogen and that hydrogen has been observed in the mixed bacterial action of marine muds. The presence of 0.36–0.70 mole per cent hydrogen in natural gas rich in helium (2) is probably derived by the action of radioactive material on the gas or other organic material. The presence of hydrogen in such gases and the absence of both hydrogen and helium in other natural gases may be regarded as a special condition of partial decomposition of gas or oil rather than a general method of origin.

7. *Differences in catalytic activity of minerals in contact with bitumen or oil.*—That the minerals in such formations do have widely different catalytic activity, as indicated by polymerization of reactive, unsaturated hydrocarbons, was shown in the previous paper.

RELATION OF PETROLEUM COMPOSITION TO CALCULATED EQUILIBRIUM MIXTURES

It was pointed out in the previous paper that the proportions of normal paraffins and isoparaffins differ widely in different oils. The widest difference is noted in the Winkler, Texas (Permian), and Greendale, Michigan (Devonian), oils. Light gasoline fractions from these crudes show 63.1 per cent normal paraffins and 13.2 per cent isoparaffins in the Michigan product, and 9.5 per cent normal paraffins and 61.6 per cent isoparaffins in the Winkler light gasoline.

The accurate and painstaking analyses made by the Bureau of Standards petroleum research group (4) of the percentage of isomeric hexanes in the light naphtha fraction from seven crude oils are shown in Table I.

TABLE I

ISOMERIC HEXANES IN LIGHT NAPHTHA, 40–102°C. OF SEVEN CRUDE OILS

Component Paraffin and Naphthene	*Ponca, Okla.*	*East Texas*	*Bradford, Pa.*	*Greendale-Kawkawlin, Mich.*	*Winkler, Texas*	*Midway, Cal.*	*Conroe, Texas*
			Percentage by Volume of Distillate				
2,2-Dimethylbutane	0.11	0.17	0.15	0.05	0.23	0.25	0.19
2,3-Dimethylbutane	0.23	0.41	0.43	0.30	0.52	0.30	0.31
2-Methylpentane	1.12	2.39	3.42	1.34	1.67	1.68	1.53
3-Methylpentane	1.04	1.82	2.04	0.88	4.18	1.14	1.07
nHexane	5.39	4.78	5.79	11.24	1.13	1.88	2.36

The calculated equilibrium percentages of the isomeric hexanes at different temperatures are shown in Figure 5.

As pointed out by A. N. Sachanen (13), the occurrence and distribution of individual hydrocarbons in straight-run gasolines and crude oils have no correlation with the thermodynamic stability of hydrocarbons. The predominance of normal paraffins in the gasolines from certain crude oils does not correspond with the relative instability of such hydrocarbons compared with branched isomers "under the low temperature conditions in which the crude oils were undoubtedly formed." Also, as expressed by Sachanen, "The isomerization of petroleum hydrocarbons, according to the free energy relations at low temperatures (*in the absence of specific catalysts*), would be just as improbable as the spontaneous decomposition of hydrocarbons into carbon, hydrogen and methane."

In alkylation processes at low temperatures in the presence of catalysts such as HF, sulphuric acid, and aluminum chloride, the hydrocarbons formed do not correspond with the equilibrium compositions.

The facts here presented are consistent with the low-temperature history

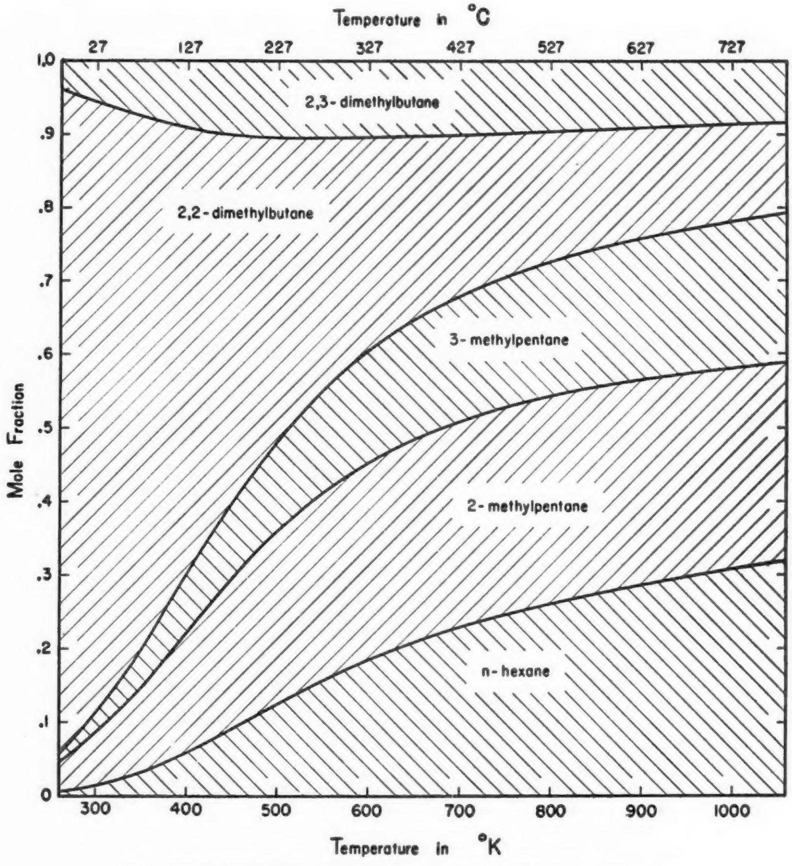


FIG. 5.—Calculated equilibrium concentrations of hexanes. Courtesy, *Journal Research, United States Bureau of Standards* (12).

of petroleum formation as shown by other chemical considerations and geological evidence. They are not inconsistent with the formation of petroleums through the action of active-surface catalysts at relatively low temperatures, acting on the original organic source material and progressively on the heavy bitumens which are probably intermediate products.

REFERENCES

1. BARTON, D. C., *Problems of Petroleum Geology*, Amer. Assoc. Petrol. Geol. (1934), pp. 109–55.
2. BREWER, A. K., AND DIBELER, V. H., "Mass Spectrometric Analyses of Hydrocarbon and Gas Mixtures," *Jour. Research*, U. S. Bur. Standards, Vol. 35 (1945), pp. 125–39.
3. BROOKS, B. T., "Role of Active-Surface Catalysts in Formation of Petroleum," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 32 (1948), p. 2271.

4. Forziati, A. F., Willingham, C. B., Mair, B. J., and Rossini, F. D., *Hydrocarbons in the Gasoline Fraction of Seven Representative Crudes*, Amer. Petrol. Inst. Division of Refining (1943), p. 38.
5. Gayer, F. H., "Catalytic Polymerization of Propylene," *Indus. and Eng. Chemistry*, Vol. 25 (1933), p. 1122.
6. Garton, E. L., "Properties of Louisiana Crude Oils," *U. S. Bur. Mines Rept. Inves. 3472* (1939).
7. Kraemer, A. J., and Wade, G., "Tabulated Analyses of Texas Crude Oils," *ibid., Tech. Paper 607* (1939).
8. Kraemer, A. J., and Garton, E. L., "Analyses of Crude Oils from Some Fields of Southern Louisiana," *ibid., Rept. Inves. 3253* (1934).
9. Lane, E. C., "Analyses of Crude Oils from Some Fields of Texas," *ibid., Rept. Inves. 3699* (1943).
10. McKinney, C. M., and Blade, O. C., "Analyses of Crude Oils from 283 Important Oil Fields in the United States," *ibid., Rept. Inves. 4289* (1948).
11. Nichols, E. A., "Geothermal Gradients in Mid-Continent and Gulf Coast Oil Fields," *Trans. Amer. Inst. Min. Eng.*, Vol. 170, Petroleum Development and Technology, 1947, pp. 44–50.
12. Rossini, F. D., Prosen, E. J., and Pitzer, K. S., "Free Energies and Equilibria of Isomerization of the Butanes, Pentanes, Hexanes and Heptanes," *Jour. Research*, U. S. Bur. Standards Vol. 27 (1941), p. 529.
13. Sachanen, A. N., *The Chemical Constituents of Petroleum* (1945), p. 212.
14. Trask, P. D., assisted by Hammar, H. E., and Wu, C. C., *Origin and Environment of Source Sediments of Petroleum* (Houston, 1932).
15. ZoBell, C. E., "Microbial Transformation of Molecular Hydrogen in Marine Sediments, with Particular Reference to Petroleum," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 31 (1947), pp. 1711–24

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 33, NO. 9 (SEPTEMBER, 1949), PP. 1613-1617, 1 FIG.

GEOLOGICAL NOTES

SLIDE RULE FOR COMPUTING CAR ODOMETER MILEAGE FROM ROAD LOGS[1]

ALBERT I. INGHAM[2]
Pittsburgh, Pennsylvania

Few modern cars are furnished with a trip odometer; the following of a geologic road log, therefore, necessitates a continual arithmetical calculation and comparison of the cumulative mileage odometer and the various points described in the road log. This process can easily lead to error because of the numerous odd-numbered and fractional mileages involved, and it also becomes a boresome procedure on a lengthy field trip. One is likely, therefore, to miss some geologic point of interest at which no stop is scheduled.

In order to obviate the use of a geologic road log with a cumulative mileage odometer the writer has devised the circular slide rule shown in Figure 1. This device consists of three main parts—an inner and an outer graduated circle made from polar coordinate paper, and a plastic arm, the two circles and arm being independently movable.

The device is made as follows. From a sheet of polar coordinate paper, accurately cut out the inner circle and mount this and the companion outer circle on separate pieces of cardboard or plastic. Each ten graduations on the circles are numbered as shown, beginning at 0, through 90 and back to 0, then continuing through 70 and returning to the original 0. Each graduation corresponds with one mile. A plastic arm (plexiglas was used although other materials would be satisfactory) is prepared, the arm being scored lengthwise with a fine grooved line and the groove filled with a colored ink. A hole is drilled through the common centers of the two circles and the arm, and the three pieces are joined with a screwtype binding post such as used to bind loose-leaf sheets. In assembling the parts, the use of one or more flat steel washers and a lock washer will reduce friction between the moving parts and lessen any tendency of the binding post to unscrew as the pieces are revolved.

An example of the use of the slide rule follows. The cumulative mileage odometer at the beginning of the field trip (0.0 on the road log) registers 53,631.8 miles. We are concerned only with the last two whole numbers and the fractional mileage, that is, 31.8. Set 31.8 on the inner circle (labelled "auto" on the slide rule) opposite 0.0 on the outer circle (labelled "log"). In making this initial setting use the portions of the arcs graduated from 0 through 90 to 0 (arcs marked with a heavy line, Figure 1) since this portion offers the maximum utilization of the circles. After setting the mileage as explained, some device should be used for

[1] Manuscript received, July 21, 1949.

[2] Geologist, Pennsylvania Geological Survey.

clamping the two circles to prevent any movement away from the original adjustment; a steel clip known as a "banker's clasp" is used by the writer. Following the setting, it is a simple matter to follow the road log without the necessity of making arithmetical calculations. For instance, if an outcrop at 10.7 miles is described in the road log, set the fine line on the plastic arm at 10.7 on the outer

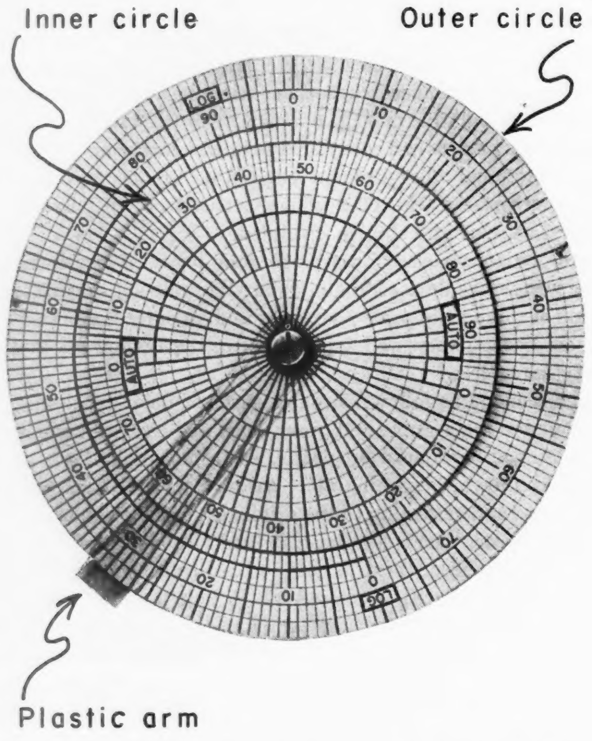


FIG. 1.—Slide rule for computing car odometer mileage from road logs.

(log) arc and read the car odometer mileage directly on the inner (auto) arc—53,642.5 miles. Subsequent observations are made similarly. The writer has found it easy to interpolate to as little as 0.2 of a mile between the one-mile graduations. If desirable, polar coordinate paper with more subdivisions may be used and each graduation made 0.5 mile. Interpolation to 0.1 mile should then be possible.

The slide rule, which was made in about 3 hours, is very durable and should last for many years. It is designed in the circular style for compactness and ease of handling. If one has a low-priced conventional straight slide rule, graph paper can be pasted over the scales, and the instrument used in a manner similar to that here described.

FORAMINIFERA OF FRANCISCAN (CALIFORNIA)[1]

MARTIN F. GLAESSNER[2]
Port Moresby, Papua, New Guinea

In a recent issue of the late Joseph A. Cushman's *Contributions*[3] an interesting fauna of smaller foraminifera from a limestone member of the Franciscan in Santa Clara County, California, is described. The following species are mentioned.

Textularia almadenensis Cushman and Todd
Gaudryina almadenensis Cushman and Todd
Pseudoclavulina californica Cushman and Todd
P. almadenensis Cushman and Todd
P. coria Cushman and Todd
Arenobulimina sp.
Dorothia? almadenensis Cushman and Todd
Tritaxilina? almadenensis Cushman and Todd
Bulimina sp.
Bolivina sp.
Gyroidina sp.
Eponides sp.
Globigerina almadenensis Cushman and Todd
G. sp.
Hastigerinella sp.
Globorotalia californica Cushman and Todd
G. decorata Cushman and Todd
G. almadenensis Cushman and Todd
Planomalina? almadenensis Cushman and Todd

The stratigraphic conclusions reached by the authors are formulated as follows. Of the fourteen genera recognized, "six genera are known from beds as old as Jurassic or older, one from Lower Cretaceous beds only, five from beds not older than Lower Cretaceous, and two from beds not older than Upper Cretaceous. Thus the foraminifera would seem to indicate that these beds are younger than Jurassic." Previously Thalmann[4] had mentioned the occurrence of *Globotruncana* in a Franciscan limestone from Santa Clara County and had placed it in the Turonian-Lower Senonian.

These conclusions seem to disagree with field geological data indicating late Jurassic (Tithonian) age of the Franciscan. According to Taliaferro[5] the Franciscan and the Knoxville, which is regarded by him as an "upper phase" of the same group, are unconformably overlain by transgressive strata containing a fauna of very early Lower Cretaceous age.

[1] Manuscript received, July 20, 1949.

[2] Chief paleontologist, Australasian Petroleum Company.

[3] J. A. Cushman and R. Todd, "A Foraminiferal Fauna from the New Almadén District, California," *Contrib. Cushman Lab. Foram. Res.*, Vol. 24 (1948), pp. 90–98, Pl. 16.

[4] H. Thalmann, "Globotruncana in the Franciscan Limestone, Santa Clara County, California" (abstract), *Bull. Geol. Soc. America*, Vol. 53 (1942), p. 1838.

[5] N. L. Taliaferro, "Geologic History and Structure of the Central Coast Range of California," *California Div. Mines Geol. Bull. 118* (1940), pp. 119–63.
———, "Franciscan-Knoxville Problem," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 27, No. 2 (February, 1943), pp. 109–219.
———, personal communication.

From a micropaleontological viewpoint, Cushman and Todd's conclusions are fully justified as no Jurassic fauna of similar composition has ever been found. A further analysis of their published data allows us to go even further and to postulate late Lower Cretaceous (Albian) age for this Franciscan limestone.

Omitting the five genera which Cushman considers as ranging down to Jurassic or lower (*Textularia*, *Gaudryina*, *Bolivina*, *Bulimina*, *Eponides*), and also *Arenobulimina*, of which a non-typical species was recently described from the Jurassic, we find that *Pseudoclavulina californica* resembles the form described by Gandolfi[6] as *P. eggeri* (Cushman) from the Albian and Cenomanian of the Southern Alps. This seems to be the lowest recorded occurrence of the genus. *Tritaxilina? almadenensis* closely resembles *Gaudryinella mendrisiensis* Gandolfi (Aptian?-Albian). *Gaudryinella* is known elsewhere from Lower Cenomanian to Recent and *Tritaxilina* from Tertiary to Recent. Nothing similar is known from the Jurassic or early Lower Cretaceous. The lowest known occurrences of *Dorothia* are in the Albian. *Gyroidina* sp. of Cushman and Todd belongs to the common Lower Cretaceous group of *G. nitida* Reuss (see Gandolfi, p. 94, Fig. 30). *Eponides* sp. (Cushman and Todd, Pl. 16, Fig. 15) seems to be identical with Gandolfi's *Discorbis* sp. (*l.c.*, p. 92, Fig. 29) from the Albian. *Hastigerinella* sp. resembles *Schackoina pentagonalis* described by Reichel[7] from the same strata. Still more important are the following relations. *Globigerina almadenensis* is close to, if not identical with, "*Anomalina*" *roberti* Gandolfi (Albian) (*l.c.*, p. 100, Pl. 2, Fig. 2; Pl. 4, Figs. 4–7, 20; Pl. 13, Figs. 3–6). "*Globorotalia*" *californica* is related to the group of *Globotruncana ticinensis*, the earliest of the single-keeled *Globotruncana* and according to Reichel an index fossil for uppermost Albian (Vraconnian). *G. decorata* represents another type of the group of *G. ticinensis* and is also very close to *G. delrioensis* (Plummer) from the Upper Albian and Lower Cenomanian and to *G. ticinensis* var. Gandolfi, while *G. almadenensis* belongs to the much discussed group of *Rotalipora*, resembling particularly *R. cushmani* (Morrow) var. *evoluta* Sigal from the basal Cenomanian. Finally, the genus *Planomalina* is represented in the Franciscan limestone by *P. almadenensis* and in Gandolfi's fauna by "*Planulina*" *buxtorfi*.

It is hard to imagine a closer relation of two faunas from distant areas. World-wide relations of foraminiferal faunas and particularly of their pelagic elements are the rule in pre-Tertiary strata. The occurrence of a high percentage of Alpine forms or their representatives on the Pacific side of the American continent will be found less surprising when similar faunas known to exist in other parts of the world are described. It is particularly important to note that in the Albian portion of the sequence of strata examined by Gandolfi the group of *Globotruncana ticinensis* is linked with *Globigerina*-like forms (placed by him in *Anomalina*) by

[6] R. Gandolfi, "Ricerche micropaleontologiche e stratigrafiche sulla Scaglia e sul Flysch cretacici dei dintorni di Balerna (Ticino)," *Riv. Ital. Pal.*, Vol. 48, Pt. 4 (1942). 160 pp., pls.

[7] M. Reichel, "Les Hantkeninidés de la Scaglia et des Couches rouges (Crétacé supérieur)," *Eclogae Geol. Helvet.*, Vol. 40, No. 2 (1947), pp. 391–409, Pl. 8.

clear evolutionary transitions. These forms which arise and disappear in the Alps within a late Lower Cretaceous sequence of limited stratigraphic range can not be expected to have co-existed elsewhere for a much longer time, in much older strata. Paleontological evidence thus indicates Albian age of the small assemblage from California. An investigation of the foraminiferal fauna of the beds overlying the Franciscan in this particular area would be of great interest and it is hoped that an effort will be made to find the cause of the discrepancy between paleontological and field geological data.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 33, NO. 9 (SEPTEMBER, 1949) PP. 1618-1622

REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library, and are available, for loan, to members and associates.

OIL FIELDS IN NORTH AMERICA, BY W. A. VER WIEBE

REVIEW BY EDWARD A. KOESTER[1]
Wichita, Kansas

Oil Fields in North America, by W. A. Ver Wiebe. 251 pp., 109 figs., 63 tables, $8\frac{1}{2}\times 11$ inches, heavy paper cover. Lithoprinted. Published by the author. 150 North Chautauqua, Wichita, Kansas. Price, $6.00.

A revised edition of Ver Wiebe's standard *Oil Fields of the United States* has long been overdue. Here we have it in a volume that includes description of oil fields of Mexico, Alaska, and Canada, as well. This summary, also describes prospective areas beyond the limits of producing fields, especially in areas outside the United States.

The introductory chapter treats of the origin, migration, and accumulation of petroleum and natural gas in a concise manner. It also includes a discussion of types of rocks in which oil and gas occur and the relative importance of each type as a reservoir of petroleum. A discussion of oil traps is followed by a classification of oil fields. It is explained that in this book the description of oil fields is on the basis of structural provinces, such as the Permian Basin Province, the Gulf Coast Province or the Rocky Mountain Province, rather than a simple geographic grouping by political subdivisions. This treatment should be equally as acceptable to the executive as to the experienced geologist or geological student.

There is a general discussion of the size and shape of each province and its structural and topographic limits. A brief description of the stratigraphic sequence is followed by a short geologic history, with special mention of tectonic activity pertinent to the formation of regional or local features responsible for the accumulation of oil. The history of exploration in each petroliferous province is treated adequately. Numerous tables show the stratigraphic section for the various parts of each province and many of the outstanding individual fields are described and illustrated. Not only is particular attention paid to the type of trap but also to the thickness, extent, and character of the producing beds, and the variations in character of the beds within the same province. The book is not overloaded with details of production statistics. Just enough production data are given to show the relative importance of the more valuable fields and provinces.

Ver Wiebe has drawn freely on the *Bulletin* and special publications of the American Association of Petroleum Geologists. The many fine illustrations which characterize the book are, for the most part, from the same source. Index maps, commonly missing in work of this sort, are included for each province, so that the reader is not groping around in an atlas in order to follow the text. Cross sections and maps have been redrafted, and many of the presentations in this volume are more clear-cut than in the original. The large page size of the work allows the inclusion of illustrations on a satisfactory scale.

The addition of Alaskan, Canadian, and Mexican fields will be welcome to those who will find this book a constantly used reference work. The Alaskan and Canadian chapters contain much recent information on these areas of increasing importance. The chapter on Mexico includes many previously unpublished data, secured by the author during his work in that country.

This book, like its predecessor, will be a "must" in any complete library of petroleum geology.

[1] Consulting geologist. Review received, July 20, 1949.

LANDSCAPE, BY C. A. COTTON

REVIEW BY BURTON WALLACE COLLINS[1]
Christchurch, New Zealand

Landscape as Developed by the Processes of Normal Erosion, by C. A. Cotton, professor of geology, Victoria University College, Wellington, New Zealand. Second edition, revised and enlarged. 509 pp., colored frontispiece, and 375 figs. 5.5×8.5 inches. Whitcombe and Tombs Limited, Christchurch, New Zealand (1948).

The first edition of this work, published in 1941 by the Cambridge University Press (Great Britain), has already become a classic and has been out of print for some years. This second edition has been printed and published in New Zealand by arrangement with the original publishers. The book has been considerably enlarged and in part rewritten, and new photographic illustrations have been added. As the first edition has already been reviewed in this *Bulletin*[2] by the present writer only the major differences between the editions are noticed here.

The size has been increased from the 301 pages, plus 44 plates of the 1941 work, to more than 500 pages. Although the number of chapters (24) remains unaltered, there has been some re-arrangement of material and many new paragraphs have been inserted. The last chapter in the new edition, on "Limestone Caverns," is entirely new, and deals with the work of ground water in limestone terranes. Chapters 15 and 16 of the first edition have been combined under one heading, "Constructional Landforms," but without abridgment —in fact with some amplification.

All illustrations are now distributed throughout the text, which is printed on good-quality coated paper giving excellent reproduction of detail in the photographs. The constant turning of pages in order to refer to the plates (which were grouped at the end of the first edition), that was criticized in the former review, has thus been eliminated. Unfortunately, Cotton's excellent line drawings seem to suffer slightly, perhaps by comparison, and do not seem to be as clear on the new paper as they were on the old. Many new aerial photographs of New Zealand landscape features have been introduced.

Minor changes include: the introduction of section headings within the chapters, making for easier reference; the grouping of bibliographic references at the ends of the chapters instead of as footnotes; and the enlargement of the index from 9 pages to 15½. It is to be noted that the index serves also as an aid in finding any particular illustration required—a useful feature as there is no separate list of illustrations.

Evidence that the revised edition is fully up-to-date is provided by the fact that there are many references to papers published since the date of publication of the first edition: papers in both New Zealand and overseas journals up to 1947 are included, and there is even a reference to a paper by Cotton that was in the press in 1948.

There is no doubt that this revision will further enhance the already high reputation of its author, and will be in demand both as a textbook for advanced students of geomorphology and for reference by geologists in general. The optimistic hope expressed by the publishers on the dust cover, that "the general reader who desires to know something of the forces that have shaped and are shaping the earth's surface will find in *Landscape* a continuous story unfolded before him," seems, however, likely to be doomed to disappointment. The book is certainly not one for the amateur. The style is, it must be admitted, in places not noteworthy for clarity. Long, involved sentences, inadequately punctuated, are not uncommon; and the author's extreme caution in dealing with controversial issues clutters the text with qualifying phrases and clauses. On the other hand,

[1] New Zealand Geological Survey, Box 374. Review received, July 26, 1949.

[2] *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 27, No. 7 (July, 1943), pp. 1013–16.

Cotton can be outspoken when he wishes, for instance in the footnote on page 246.

Some textbook statements on the subject [valley-plain alluvial deposits] are either very vague or actually misleading and show a more or less complete failure on the part of the authors to understand flood-plain development and alluvial accumulation (e.g., R. S. Tarr, *New Physical Geography*, New York, 1909, p. 61, and A. Holmes, *Principles of Physical Geology*, London, 1944, p. 167 and Fig. 77).

RECENT PUBLICATIONS

APPALACHIANS

"Early Silurian Rocks of the Northern Appalachian Basin," by Gordon Rittenhouse. *U. S. Geol. Survey Prelim. Map 100* (1949), Oil and Gas Inves. Ser. Sheet, 33×54 inches, includes 3 maps and 2 cross sections. May be purchased from Director, U. S. Geological Survey, Washington 25, D. C. Price, $0.40.

*"The Base of the Cambrian in the Southern Appalachians, Part I," by Philip B. King. *Amer. Jour. Sci.*, Vol. 247, No. 8 (New Haven, Connecticut, August, 1949), pp. 513–30; 6 figs.

ARIZONA

*"Lower Cretaceous Stratigraphy in Southeastern Arizona," by Alexander Stoyanow. *Geol. Soc. America Mem. 38* (New York, July 8, 1949). 156 pp., 27 pls., 2 figs.

BRAZIL

*"Polychaete Annelids from the Devonian of Parana, Brazil," by Frederico Waldemar Lange. *Bulletins Amer. Paleon.*, Vol. 33, No. 134 (Paleontological Research Institution, Ithaca, New York, June 11, 1949). 104 pp., 16 pls., 3 figs.

BURMA

*"On the Occurrence of Biplanispira in the Uppermost Eocene (Kyet-U-Bok Band) of Burma," by C. Beets. *Geologie en Mijnbouw*, Vol. 11, No. 7 (July, 1949), pp. 229–32; 1 fig. G. A. Tiesing, Vogelkersstraat 48, 's-Gravenhage, Holland.

CALIFORNIA

*"The Edna Tar Sands," *anon. California Oil World*, Vol. 42, No. 13 (Los Angeles, July, 1949), pp. 3–11; 4 figs.

CANADA

"Some Cretaceous Sections along Athabaska River from the Mouth of Calling River to below Grand Rapids, Alberta," by R. T. D. Wickenden.

CHINA

*"The Amadeus William Grabau Memorial Volume," by many authors. *Bull. Geol. Soc. China*, Vol. 27 (Nanking, November, 1947). 412 pp., illus. Contains biographical notes and memorials of Grabau, and 24 geological papers, including "A Review of the Stratigraphy, Structure, and Geological History of the Szechuan Red Basin and the Occurrence of Natural Gas, Oil, Brines, and Rock Salt Contained Therein, with Special Discussions of Their Origin and Future Prospects," by C. Y. Hsieh, pp. 55–84; 7 tables, 1 pl. 7.5×10.25 inches. Paper covers. In English.

GENERAL

*"Actualism in Epeirogenetic Oceans," by M. G. Rutten. *Geologie en Mijnbouw*, Vol. 11, No. 7 (July, 1949), pp. 222–28. G. A. Tiesing, Vogelkersstraat 48, 's-Gravenhage, Holland.

*"Quantitative Areal Geology of the United States," by Donald V. Higgs. *Amer. Jour. Sci.*, Vol. 247, No. 8 (New Haven, Connecticut, August, 1949), pp. 575–83; 5 figs.

*"Report of the Committee on the Measurement of Geologic Time, 1947–1948," by John Putnam Marble, chairman. *Nat. Research Council Div. Geol. and Geogr.* (Washington, D. C., June, 1949). 77 multigraphed pp. 8.5×11 inches. Price, $1.00.

*"Geologic Mapping in the United States," by Leona Boardman. *Bull. Geol. Soc. America*, Vol. 60, No. 7 (New York, July, 1949), pp. 1125–32; 3 figs., 1 pl.

GERMANY

*"Der Tiefere Untergrund des westlichen Peribaltikums," by Rudolf von Zwerger. *Abh. Geol. Landesanstalt Berlin*, Neue Folge, Heft 210. 74 pp., 3 pls. (maps in color), 11 figs. Significance of regional gravity and magnetic disturbance. Akad.—Verlag G M B H, Berlin (1948). German.

GREAT BRITAIN

*"A Structure Contour Map of the Surface of the Buried Pre-Permian Rocks of England and Wales," by P. E. Kent. *Proc. Geologists' Assoc.*, Vol. 60, Pt. 2 (June 30, 1949), pp. 87–104; 3 figs., 1 pl. Benham and Company, Ltd., High Street, Colchester, England. Price of issue, 5/-.

*"The Geology of the Eastern Part of the English Channel," by William Bernard Robinson King. *Quar. Jour. Geol. Soc. London*, Vol. 104, No. 415, Pt. 3 (March 9, 1949), pp. 327–38; 1 fig., 1 pl. Longmans, Green and Company, Ltd., 6–7 Clifford Street, London, W. 1, England. Price of issue, 10s.

*"Gravity Data Obtained in Great Britain by the Anglo-American Oil Company, Limited," by Peter H. N. White. *Ibid.*, pp. 339–64; 4 pls., 3 figs.

*"Slumping in the Carboniferous Rocks of Pembrokeshire," by Philip Henry Kuener. *Ibid.*, pp. 365–86; 10 figs., 6 pls.

*"The Devolitilization of Coal Seams in South Wales," by Frederick Murray Trotter. *Ibid.*, pp. 387–437; 12 figs.

ILLINOIS

*"Illinois Fluid Injection Research Reviewed," Frederick Squires. *Producers Monthly*, Vol. 13, No. 9 (Bradford, Pennsylvania, July, 1949), pp. 32–43; 35 figs.

IRAN

*"Drilling Practices in Iran," by H. W. Lane. *Oil and Gas Jour.*, Vol. 48, No. 13 (Tulsa, Oklahoma, August 4, 1949), pp. 56–61; 4 figs. Contains geologic sections.

KANSAS

*"Method of Prospecting for Kansas Shoestrings," by Orton E. Campbell. *World Oil*, Vol. 129, No. 4 (Houston, Texas, August, 1949), pp. 62–64; 3 figs.

NEW MEXICO

*"New Mexico Oil and Gas Statistical Data for 1948," compiled by E. E. Kinney, Lea County Operators Committee, and New Mexico Oil Conservation Commission. *New Mexico Bur. Mines and Min. Resources Oil and Gas Rept. 4-A* (Socorro, 1949). 386 pp. Multigraphed, 8.5×11 inches. Paper cover. Price, $2.25.

*"Geology of the Manzanita and North Manzano Mountains, New Mexico," by Parry Reiche. *Bull. Geol. Soc. America*, Vol. 60, No. 7 (New York, July, 1949), pp. 1183–1212; 5 figs., 6 pls.

PENNSYLVANIA

*"The Fault at the West Edge of the Triassic in Southern Pennsylvania," by George W. Stose. *Amer. Jour. Sci.*, Vol. 247, No. 8 (New Haven, Connecticut, August, 1949), pp. 531–36; 3 figs.

ROCKY MOUNTAINS

*"The Greater San Juan Basin," by John Leeds Kerr. *World Oil*, Vol. 129, No. 4 (Houston, Texas, August, 1949), pp. 66–74; 1 map.

TEXAS

*"Stratigraphy and Petrology of Buck Hill Quadrangle, Texas," by S. S. Goldich and M. A. Elms. *Bull. Geol. Soc. America*, Vol. 60, No. 7 (New York, July, 1949), pp. 1133–82; 6 figs., 6 pls.

WYOMING

"Stratigraphic Sections of Pre-Cody Upper Cretaceous Rocks in Central Wyoming," by Raymond M. Thompson, J. D. Love, and Harry A. Tourtelot. *U. S. Geol. Survey Prelim. Chart 36*, Oil and Gas Inves. Ser. (August, 1949). 2 sheets, each 40×52 inches. Columnar sections, index map, table of rock units, and text. Map Distribution Office, U. S. Geological Survey, Denver Federal Center, Denver, Colorado. Price, $0.75.

"Geology of the Hartville Uplift, Eastern Wyoming," by N. M. Denson and Theodore Botinelly. *Ibid., Prelim. Map 102.* 2 sheets, each 44×56 inches. Geologic map, columnar sections, small-scale thickness maps, cross sections, text. Price, $1.00.

"Geology of the Mush Creek and Osage Oil Fields and Vicinity, Weston County, Wyoming," by C. E. Dobbin and G. H. Horn. *Ibid., Prelim. Map 103.* Sheet 34×52 inches. Structure contour, index map, cross section, columnar section, text. Price, $0.50.

ASSOCIATION DIVISION OF PALEONTOLOGY AND MINERALOGY

**Journal of Paleontology* (Tulsa, Oklahoma), Vol. 23, No. 4 (July, 1949).

"Trilobite Fauna of the Upper Cambrian Honey Creek Formation," by E. A. Frederickson.

"The Ostracode Genus *Eucytherura* and Its Species from the Cretaceous and Tertiary of the Gulf Coast," by Leo Weingeist.

"Allegheny Conodonts from Eastern Ohio," by Myron T. Sturgeon and Walter Youngquist.

"A Giant Scaphopod from the Pennsylvanian of Texas," by A. K. Miller.

"Two New Species of Gastropods from the Middle Eocene of California," by G. Dallas Hanna and Leo George Hertlein.

"Bibliography and Index to New Genera, Species, and Varieties of Foraminifera for the Year 1947," by Hans E. Thalmann.

"Foraminifera in the Upper Tertiary of Egypt," by R. M. Stainforth.

"New Miocene Foraminifera from Japan," by Kiyoshi Asano.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 33, NO. 9 (SEPTEMBER, 1949), PP. 1623-1636

THE ASSOCIATION ROUND TABLE

ASSOCIATION COMMITTEES*

EXECUTIVE COMMITTEE (1950)

C. W. TOMLINSON, *chairman*, Ardmore, Oklahoma
HENRY N. TOLER, *secretary*, Southern Natural Gas Company, Jackson, Mississippi
PAUL WEAVER, Gulf Oil Corporation, Houston, Texas
T. A. LINK, consultant, Toronto, Ontario
ALFRED H. BELL, Illinois Geological Survey, Urbana, Illinois

DIRECTORS OF AMERICAN GEOLOGICAL INSTITUTE (2-yr. term)

W. B. HEROY (Nov., 1949) PAUL WEAVER (Nov., 1950)

REPRESENTATIVE ON DIVISION OF GEOLOGY AND GEOGRAPHY NATIONAL RESEARCH COUNCIL (3-yr. term)

WALTER B. LANG (June, 1952)

REPRESENTATIVES ON COUNCIL OF AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE (2-yr. term)

W. TAYLOR THOM, JR. (Dec., 1949) ROBERT J. RIGGS (Dec., 1949)

COMMISSIONERS ON AMERICAN COMMISSION ON STRATIGRAPHIC NOMENCLATURE (3-yr. term)

W. V. JONES (Dec., 1949), *chairman* M. G. CHENEY (Dec., 1950) JOHN G. BARTRAM (Dec., 1951)

STANDING COMMITTEES

FINANCE COMMITTEE

E. O. MARKHAM (1950) JOSEPH E. POGUE (1951), *chairman* JOHN S. IVY (1952)

TRUSTEES OF REVOLVING PUBLICATION FUND

HAROLD W. HOOTS (1950) W. B. WILSON (1951)

TRUSTEES OF RESEARCH FUND

ROY R. MORSE (1950) T. S. HARRISON (1951), *chairman*

BUSINESS COMMITTEE

ALFRED H. BELL (1950)
E. J. BOOS (1950)
RALPH A. BRANT (1950)
C. E. BREHM (1951)
J. A. BROWN (1950)
W. Z. BURKHEAD (1951)
RALPH B. CANTRELL (1950)
FRANK B. CARTER (1950)
WALTER M. CHAPPELL (1950)
HOMER H. CHARLES (1950)
JOHN W. CLARK (1950)
W. H. CONKLING (1951)
KARL DALLMUS (1951)
MAX DAVID (1950)
D. E. EDSTROM (1951)
H. C. FERGUSON (1950)
L. E. FITTS, JR. (1951)
THOMAS J. FITZGERALD (1950)
KIRK C. FORCADE (1950)
PETER H. GARDETT (1951)
W. W. HAMMOND (1951)
DAVID C. HARRELL (1951)
JACK H. HEATHMAN (1951)
ADEN W. HUGHES (1951)
J. S. HUDNALL (1951)
HAROLD J. KLEEN (1951)
CECIL G. LALICKER (1950)
NOEL R. LAMB (1951)
T. A. LINK (1950)
WALTER K. LINK (1950)
J. B. LOVEJOY (1951)
O. G. MCCLAIN (1951)
ROBERT B. MICHELL (1950)
MARION J. MOORE (1950)
A. N. MURRAY (1951)
MANLEY L. NATLAND (1951)
R. B. NEWCOMBE (1951)
FRANK A. OYSTER (1951)
R. D. PATTERSON (1951)
VINCENT C. PERINI, JR. (1950)
W. G. PIERCE (1950)
R. DOUGLAS ROGERS (1951)
A. L. SELIG (1950)
G. J. SMITH (1951)
ALLISON J. SOLARI (1950)
R. A. STEHR (1951)
HENRYK B. STENZEL (1950)
HENRY N. TOLER (1950)
C. W. TOMLINSON (1951)
R. B. TOTTEN (1950)
D. D. UTTERBACK (1951)
C. N. VALERIUS (1951)
PAUL WEAVER (1950)
J. B. WEBB (1951)
JEROME B. WESTHEIMER (1950)
JAMES E. WILSON (1950)
BRUNO O. WINKLER (1951)

* Terms of individuals expire at close of annual meeting in April of year indicated, unless another month is shown.

COMMITTEE FOR PUBLICATION

George C. Grow, Jr. (1952), *chairman*, Peoples Natural Gas Company, Pittsburgh, Pa.

1950	1951	1952
Hollis D. Hedberg	John E. Galley	John G. Gray
G. L. Meholin	E. Russell Lloyd	Benjamin F. Hake
E. Floyd Miller	Homer A. Noble	Mason L. Hill
Vincent C. Perini, Jr.	Thomas H. Philpott	George S. Hume
Paul H. Price	Dolphe E. Simic	James A. Moore
E. E. Rehn	R. D. White	Manley Osgood, Jr.
J. K. Rogers	C. W. Wilson, Jr.	E. A. Wendlandt
K. K. Spooner		

RESEARCH COMMITTEE

John T. Rouse, Jr. (1950), *chairman*, Magnolia Petroleum Company, Dallas, Texas

1950	1951	1952
Roland F. Beers	D. L. Blackstone, Jr.	Dale L. Benson
G. C. Gester	William R. Canada	Joseph R. Clair
John T. Lonsdale	Stanley C. Herold	Ralph D. Chambers
C. V. Millikan	Walter K. Link	Parke A. Dickey
M. L. Natland, *ex. off.* SEPM	S. W. Lowman	Marcus A. Hanna
L. L. Nettleton	F. W. Rolshausen	Daniel John Jones
Paul H. Price	Robert J. Seale	Robert M. Swesnik
W. H. Twenhofel	David H. Swann	Garvin L. Taylor
Claude E. ZoBell	Georges Vorbe	

GEOLOGIC NAMES AND CORRELATIONS COMMITTEE

Henry J. Morgan, Jr. (1951), *chairman*, Atlantic Oil and Refining Company, Dallas, Texas

1950	1951	1952
C. I. Alexander	Hugh H. Beach	Charles F. Bassett
Stuart K. Clark	M. G. Cheney	George V. Cohee
W. J. Hilseweck	E. J. Combs	I. Curtis Hicks
P. H. Jennings	Robert H. Dott	Thomas C. Hiestand
Wayne V. Jones	Herman Gunter	Frederic F. Mellen
W. Armstrong Price	Raymond C. Moore	Arthur M. Meyer
H. A. Tourtelot		Grover E. Murray
		Horace G. Richards
		L. E. Workman

COMMITTEE ON APPLICATIONS OF GEOLOGY

Karl A. Mygdal (1951), *chairman*, Pure Oil Company, Chicago, Illinois

1950	1951	1952
Don L. Carroll	John B. Fanshawe	Charles A. Deegan
Stanley G. Elder	Henry D. McCallum	R. A. Stehr
Leo R. Fortier	Carl B. Richardson	
Thomas A. Hendricks	Maynard H. Steig	
W. T. Nightingale		
W. T. Schneider		

MEDAL AWARD COMMITTEE

C. W. Tomlinson, *chairman*, Ardmore, Oklahoma
H. B. Stenzel, *ex officio*, president of S.E.P.M.
Andrew Gilmour, *ex officio*, president of S.E.G.

1950	1951	1952
Frank R. Clark	Henry A. Ley	Wallace E. Pratt
Alfred H. Bell	Gordon I. Atwater	Frederick A. Bush
A. E. Brainerd	R. E. Sherrill	J. V. Howell
	H. V. Tygrett	

COMMITTEE ON STATISTICS OF EXPLORATORY DRILLING

F. H. LAHEE (1950), *chairman*, Sun Oil Company, Box 2880, Dallas, Texas
GRAHAM B. MOODY (1951), *vice-chairman* Standard Oil Co. of California, San Francisco

1950	1951	1952
WALTER L. AMMON	KENNETH C. BERESFORD	J. A. BROWN
A. H. BELL	KENNETH COTTINGHAM	COLEMAN D. HUNTER
DELMAR O. BRANSON	GEORGE C. GROW, JR.	ROBERT C. LAFFERTY, JR.
R. J. CULLEN	OSCAR M. HUDSON	H. H. LESTER
W. S. MCCABE	CHARLES H. ROW	LAURENCE S. MELZER
H. J. MCLELLAN	A. N. SHARRICK	D. J. MUNROE
T. F. PETTY	F. B. STEIN	GLENN C. SLEIGHT
R. M. WILSON	PAUL WEAVER	PAUL H. UMBACH

DISTINGUISHED LECTURE COMMITTEE

HAROLD T. MORLEY (1952), *chairman*, Stanolind Oil and Gas Company, Tulsa, Oklahoma

1950	1951	1952
JOHN L. FERGUSON	HERSCHEL H. COOPER	H. J. BUDDENHAGEN
W. J. HILSEWECK	K. K. LANDES	ROBERT E. RETTGER
FRED H. MOORE	ELLIOT H. POWERS	
	E. E. REHN	

SPECIAL COMMITTEES

COMMITTEE ON BOY SCOUTS LITERATURE

FRANK GOUIN, *chairman*, Box 208, Duncan, Oklahoma

A. C. BACE	C. L. COOPER	RAY L. SIX
MAX W. BALL	G. C. GESTER	R. C. SPIVEY
DON L. CARROLL	DON B. GOULD	W. T. THOM, JR.
		RUSSELL M. TRIPP

COMMITTEE ON NATIONAL RESPONSIBILITY

COLONEL O. F. KOTICK, *chairman*, Navy Petroleum Reserves, Building T-3, Room 1046, Navy Department, Washington, D. C.

FRITZ L. AURIN	DON L. CARROLL	BEN F. HAKE
MAX W. BALL	CARLE H. DANE	WILLIAM B. HEROY
OLIN G. BELL	A. RODGER DENISON	C. T. JONES
		EDMUND M. SPIEKER

CONSTITUTION AND BY-LAWS—ERRATA

In the constitution as printed on page 1447 of the August *Bulletin*, the last four lines in the paragraph stating the requirements for members (Art. III, Sec. 1) should read:

. . . and provided further that these requirements shall not be construed to exclude teachers and research workers *in geology* in recognized institutions, whose work is of such character as in the opinion of the executive committee shall qualify them for membership.

In the by-laws as printed on page 1456 of the August *Bulletin*, the paragraph on the Committee on Statistics of Exploratory Drilling (Art. VI, Sec. 12) should read:

The function of the committee on statistics of exploratory drilling shall be to assemble and compile statistics on exploratory wells and on the results of exploratory drilling for oil and gas, and annually to submit for publication in the *Bulletin* a report summarizing and analyzing these data. This committee shall consist of thirty-five members unless a different number is authorized by the executive committee.

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

At the recommendation of the A.A.P.G. committee on national responsibility, in order to attain its objective "to plan and advise with the Military Services for the effective application of geology and the efficient functioning of geologists within the Military Services," the executive committee is requesting each applicant for membership to return a statement of his World War II service and his present reserve status, if any, for which purpose a special blank is furnished by Association Headquarters, Box 979, Tulsa 1, Oklahoma.

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 979, Tulsa 1, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

To comply with the new amendments affecting qualifications for membership, new applicants and their sponsors should hereafter use new (1949) application forms and the new (1949) constitution and by-laws. Old forms should be destroyed.

FOR ACTIVE MEMBERSHIP

Howard Elmer Shaw, Grand Isle, La.
E. A. Murchison, Jr., O. W. Noland, J. L. Patton
Anna Marie Stanley, Casper, Wyo.
James A. Waters, F. H. Lahee, E. W. Hard
John Edwards Wolcott, Oklahoma City, Okla.
Thomas H. Green, Don L. Hyatt, W. O. Thompson

FOR ASSOCIATE MEMBERSHIP

John P. Baughman, Craig, Colo.
G. W. Beer, James W. Nance, Ross L. Heaton
Thomas Beard, Ann Arbor, Mich.
A. J. Eardley, K. K. Landes, R. C. Hussey
Glen D. Brooks, Wichita Falls, Tex.
Leroy T. Patton, C. A. Renfroe, Raymond Sidwell
Robert Daniel Carter, Corpus Christi, Tex.
Hal P. Bybee, H. Gordon Damon, C. E. Buck
James Michael Drexler, Ann Arbor, Mich.
A. J. Eardley, E. C. Stumm, K. K. Landes
Fred Ahrens Ealand, Tallahassee, Fla.
F. M. Bullard, W. C. Blackburn, H. B. Stenzel
Ralph Irving Ellsworth, Madisonville, Tex.
Harry H. Power, H. Gordon Damon, G. K. Eifler, Jr.
Robert Wright McDowell, Jr., Norman, Okla.
E. L. Lucas, V. E. Monnett, Homer C. Moore
Earl Hatcher Michie, Norman, Okla.
Charles E. Decker, V. E. Monnett, Carl A. Moore
John Vernon Newhouser, Golden, Colo.
J. Harlan Johnson, F. M. Van Tuyl, W. S. Levings
Walter Cadesman Pope, III, Tyler, Tex.
Delmar O. Branson, G. C. Clark, Ray Youngmeyer
Noonan Albert Prince, Bossier City, La.
A. F. Childers, Hershal C. Ferguson, Mary L. Holland
Andrew Jackson Rowe, Jr., Fort Worth, Tex.
Samuel P. Ellison, Jr., Hal P. Bybee, Irvin J. Anderson
William Paine Ryman, Matagorda, Tex.
A. F. Childers, Jr., Hershal C. Ferguson, Mary L. Holland

Dan Herbert Schusterman, Norman, Okla.
E. L. Lucas, V. E. Monnett, Keith M. Hussey
Robert Bolling Stewart, Jr., Sayre, Okla.
William D. Neiler, Robert M. Becker, W. A. Ver Wiebe
George Robert Stocker, Evansville, Ind.
I. J. Pierce, B. D. Bounds, J. H. DeLong, Jr.
James Byrl Tartt, Houston, Tex.
P. M. Konkel, W. A. Thomas, John P. Paschall
Robert Cuthrell Treadwell, Houston, Tex.
G. R. McNutt, F. L. Whitney, Hal P. Bybee

SUPPLEMENTARY MEMBERSHIP LIST, SEPTEMBER 1, 1949

Members	125
Associates	362
Total additions since publication of list in March *Bulletin*	487

FIRST LIST

‖Adams, Linn F., The California Co., Box 890, Lexington, Ky.
‖Adams, Richard D., Okla. Nat. Gas Co., Tulsa, Okla.
‖Aguerrevere-Porregas, Juan Jose, Creole Petr. Corp., Apt. 1253, Caracas, Venezuela, S. A.
‖Allen, Lundy Otie, Sells Petr. Inc., Gladewater, Tex.
‖Alliger, Jerald, Geophoto Services, 305 E. & C. Bldg., Denver, Colo.
‖Allred, Otis Bernard, Sinclair Oil & Gas Co., Midland Tex.
Anderson, Irvin J., Stanolind Oil & Gas Co., Box 1518, Lake Charles, La.
Armstrong, Lee Charles, E. J. Longyear Co., 1701 Foshay Tower, Minneapolis, Minn.
Babione, Herbert Allen, Humble Oil & Refg. Co., 612 S. Flower St., Los Angeles, Calif.
‖Baer, Karl Eugene, Box 753, Jacksboro, Tex.
‖Baker, James Sadler, Socony-Vacuum Oil Co., Inc., 26 Broadway, New York, N. Y.
Banks, Luis Maria, 807 Transit Tower Bldg., San Antonio, Tex.
‖Barkley, Carlos Junior, Shell Oil Co., Inc., Box 2099, Houston, Tex.
‖Barnett, John Abner, Jr., Seaboard Oil Co. of Delaware, Abilene, Tex.
Barr, Charles R., Stanolind Oil & Gas Co., Box 1540, Midland, Tex.
‖Battalora, George Clarence, Jr., 92 Fontainebleau Dr., New Orleans, La.
Beck, Ronald Eugene, Phillips Petr. Co., Hotel Alvin Bldg., Alvin, Tex.
Bell, William Charles, Univ. of Minnesota, St. Paul, Minn.
Bengtson, Carl Anders, Standard Oil Co. of Calif., Box 1200, Bakersfield, Calif.
‖Benner, Richard Walter, The Texas Co., Box 110, Lewistown, Mont.
‖Bergren, Arthur Learoyde, Jr., Pure Oil Co., Box 811, Durango, Colo.
‖Berry, Robert Webster, Amerada Petr. Co., 1414 Natl. Bank of Commerce Bldg., San Antonio, Tex.
‖Black, Robert John, Pure Oil Co., Box 671, Midland, Tex.
‖Blake, Mabel Louise, Shell Oil Co., Inc., Shreveport, La.
‖Blankenship, Gilbert Howard, Jr., Pure Oil Co., Box 671, Midland, Tex.
‖Boeckerman, Ruth Bastanchury, 2825 Troy St., Dayton, Ohio
Bogardus, Robert Stephen, Standard Oil Co. of Texas, Box 1660, Midland, Tex.
Boissonnas, Eric Henri, Geolectric Explor. Co., Box 550, Ridgefield, Conn.
Bowles, Edgar Oliver, The American Univ., Washington, D. C.
Boyd, Frank A., The Manufacturers Light & Heat Co., 800 Union Trust Bldg., Pittsburgh, Pa.
‖Brace, Robert Duane, Standard Oil Co. of Calif., Los Angeles, Calif.
‖Bradford, William David, British-American Oil Prod. Co., 2407 First Natl. Bank Bldg., Oklahoma City, Okla.
‖Braislin, Dana B., Jr., Union Oil Co. of Calif., Los Angeles, Calif.
Branson, Herberta Van Pelt, Shell Oil Co., Inc., Box 1191, Tulsa, Okla.
Brasher, Nugent Truitt, Stanolind Oil & Gas Co., Midland, Tex.
‖Bratt, Curtis Carrol, Phillips Petr. Co., Box 393, Chickasha, Okla.
‖Bratt, Elliott Charles, Cooperative Refg. Assn., Wichita, Kan.
‖Brechtel, Frederick Charles, Box 7653, Univ. Sta., Baton Rouge, La.
Brewster, Doris Jean, Stanolind Oil & Gas Co., Tulsa, Okla.
‖Bridges, James Marion, Danciger Oil & Refg. Co., Baton Rouge, La.
‖Brillhart, Robert Ross, Tide Water Assoc. Oil Co., Box 870, Lafayette, La.
‖Brixey, Austin Day, Jr., Sinclair Oil Corp., 630 Fifth Ave., New York, N. Y.

Broughton, John Gerard, New York State Science Service, 448 Education Bldg., Albany, N.Y.
Brown, Lyle Martin, Sun Oil Co., Box 1270, McAllen, Tex.
Brown, Walter W., Sohio Petr. Co., Abilene, Tex.
Bryant, James Elwood, The Texas Co., Box 2332, Houston, Tex.
Bryant, James Keith, Canadian Gulf Oil Co., 301–319 Sixth Ave. W., Calgary, Alta., Canada
Bryson, Richard Steele, 817 Fifteenth St., Golden, Colo.
Caldwell, Dave Lynam, Barnsdall Oil Co., 913 Petr. Bldg., Los Angeles, Calif.
Cameron, Harriet V., Louisiana State Univ., Baton Rouge, La.
Carl, William Evans, 2431 Shakespeare Rd., Houston, Tex.
Carr, William Lester, Pure Oil Co., Box 66, Clare, Mich.
Carter, Randall Bruce, Gulf Research & Devel. Co., Riverton, Wyo.
Caston, John Ernest Frederick, Texas Petr. Co., Apt. 267, Caracas, Venezuela, S. A.
Chamberlain, John David, The Texas Co., Box 110, Lewistown, Mont.
Champion, John Guadalupe, Humble Oil & Refg. Co., Box 506, Tallahassee, Fla.
Christmann, Charles Edward, Box 458, Ruidoso, N. Mex.
Clark, Clifton W., independent, Wichita Natl. Bank Bldg., Wichita Falls, Tex.
Clark, Don R., Union Oil Co. of Calif., 321-A Seventh Ave., W., Calgary, Alta., Canada
Clark, Erwin Walter, Standard Oil Co. of Calif., 225 Bush St., San Francisco, Calif.
Clark, James Warren, Amerada Petr. Corp., Drawer D, Monument, N. Mex.
Clay, John Otis, The California Co., New Orleans, La.
Clewell, Dayton Harris, Magnolia Petr. Co., Box 900, Dallas, Tex.
Cole, Clarence A., Trowbridge Sample Service, 212 Ricou-Brewster Bldg., Shreveport, La.
Collier, Lester David, Rt. 5, Box 275, Palestine, Tex.
Coppinger, John Edward, Box 612, Cross Plains, Tex.
Crawford, Paul D., consulting, 1421 Milam Bldg., San Antonio, Tex.
Critz, James Stubbs, 2632 Talbot St., Houston, Tex.
Crouch, Robert W., Richfield Oil Corp., Box 470, Long Beach, Calif.
Crouere, Jeffre John, The California Co., New Orleans, La.
Curtis, Ben Frank, Skelly Oil Co., Shreveport, La.
Cutter, Russell Cummings, Socony-Vacuum Oil Co., Caracas, Venezuela, S. A.
Daniels, Carl U., 405 W. Twenty-first St., Austin, Tex.
Darling, Gordon Bruce, Imperial Oil Ltd., 300 Ninth Ave., W., Calgary, Alta., Canada
Davis, Elliott, consulting, 2548 E. Twentieth St., Tulsa, Okla.
Deal, Clyde Stanley, Phillips Oil Co., Apt. 1031, Caracas, Venezuela, S. A.
Dean, Hal Stone, 2271 Williams St., Palo Alto, Calif.
de Bremaecker, Jean-Claude, Pan-American House, Louisiana State Univ., Baton Rouge, La.
De Hart, Berchman H., Jr., Tide Water Assoc. Oil Co., Box 870, Lafayette, La.
de Jong, Jan Diederik, Crayenestersingel 12, Heemstede, Holland
Deuth, John Eakle, 2301 Adams Ave., Evansville, Ind.
de Wys, Jane B. Negus, 2181 Briarwood Rd., Cleveland Heights, Ohio
Dickey, Robert Huey, Pure Oil Co., Box 700, Worland, Wyo.
Doane, George H., Shell Oil Co., Inc., 2080 Obispo Ave., Long Beach, Calif.
Dodge, Charles Fremont, North Texas Agri. College, Arlington, Tex.
Domenico, Norman Samuel, Amerada Petr. Corp., Denver, Colo.
Douglas, Eugene R., Atlantic Refg. Co., Midland, Tex.
Dungan, Roger Max, Continental Oil Co., Box 1766, Ventura, Calif.
Edwards, John Leslie, 750½ DeBarr, Norman, Okla.
Egeran, Enver Necdet, Maden Tetkik ve Arama Enstitusu, Ankara, Turkey
Eisner, Stephan M., Amerada Petr. Corp., Kerr-McGee Bldg., Oklahoma City, Okla.
Ekstrom, James Jack, 7304 Jefferson, Kansas City, Mo.
Ellis, Fred M., Miller & Shiarella, Box 247, Owensboro, Ky.
Eppler, James Layton, Pan-American Prod. Co., Houston, Tex.
Espy, Curtis Leach, Shell Oil Co., Inc., Box 2099, Houston, Tex.
Eustis, Lawrence Bres, Gulf Refg. Co., Box 37, Harvey, La.
Fackler, William Corliss, 5300 Chateau Pl., Minneapolis, Minn.
Faggioli, Richard Elia, Humble Oil & Refg. Co., Santa Monica, Calif.
Fazekas, John Alexander Erde'lyi, Univ. of Oklahoma, Norman, Okla.
Fedderson, Glenn Marion, 2719 Wyandot St., Denver, Colo.
Feder, Harry Robert, Chanslor-Canfield Midway Oil Co., 4549 Produce Plaza, W., Los Angeles, Calif.
Finerty, Joseph Robert, Arkansas Fuel Oil Co., 1707 Milam Bldg., San Antonio, Tex.
Finley, Dale C., Jr., Pure Oil Co., Box 311, Olney, Ill.
Fisk, Edward Penn, 119 N. Belmont Ave., Los Angeles, Calif.
Fitting, Robert Dancy, consulting, Box 1299, Midland, Tex.

||Ford, Declan Phillip, Tide Water Assoc. Oil Co., 308 Hopkins Bldg., Bakersfield, Calif.
Frebold, Hans Wilhelm Ludwig, Danish-American Prospecting Co., Copenhagen, Denmark
||Frick, John D., 562 Gayley Ave., Los Angeles, Calif.
||Gahring, Ross Rogers, Phillips Petr. Co., Ardmore, Okla.
||Ganopole, Gerald, Seaboard Oil Co., Bakersfield, Calif.
||Gatchell, John Hamilton, Atlantic Refg. Co., 830 Kennedy Bldg., Tulsa, Okla.
||Gibson, William Hunter, The Texas Co., Houston, Tex.
||Goth, Joseph Herman, Jr., Continental Oil Co., Box 1121, Durango, Colo.
Granger, Arthur Earle, U. S. Geol. Survey, 506 Federal Bldg., Salt Lake City, Utah
Grawe, Oliver R., Missouri School of Mines, Rolla, Mo.
||Gray, Lloyd George, Phillips Petr. Co., 816 Patterson Bldg., Denver, Colo.
||Greenwood, Eugene, 3313 Ada St., Fort Worth, Tex.
Griffith, Earl Gordon, The Texas Co., Box 110, Lewistown, Mont.
||Griffith, James Hendrie, Magnolia Petr. Co., Oklahoma City, Okla.
||Grimes, Robert William, Texas Petr. Co., Apt. 267, Caracas, Venezuela, S. A.
Grivetti, Rex Michael, The Texas Co., Box 327, Taft, Calif.
Gunther, Albert E., Shell Petr. Co., St. Helen's Court, Great St. Helen's, London, E.C.3, England
||Gwynn, Thomas Andrew, consulting, 909 Electric Bldg., Houston, Tex.
||Hager, Robert Louis, 20 E. Eighteenth St., Brooklyn, N. Y.
||Halamicek, William Arnold, Jr., 314 W. Harris, San Angelo, Tex.
||Hale, Earl P., Gulf Refg. Co., Box 377, Harvey, La.
||Hale, Lyle A., Amerada Petr. Corp., Afton, Wyo.
||Hall, John Frederick, Ohio State Univ., Columbus, Ohio.
||Halpenny, Leonard C., U. S. Geol. Survey, Tucson, Ariz.
||Hamilton, Edwin Lee, Apt. 14, Bldg. 315, Stanford, Calif.
||Hammond, Jackson Horton, Shell Oil Co., Inc., 2080 Obispo Ave., Long Beach, Calif.
||Hannifan, John Kerwin, Shell Oil Co., Inc., Oklahoma City, Okla.
Hanson, Edwin Victor, 2408 Prospect St., Houston, Tex.
||Hardin, Frank, R., Barnsdall Oil Co., 517 Pioneer Bldg., Lake Charles, La.
||Harmon, James Maurice, The Texas Co., Box 726, Farmington, N. Mex.
Harp, John Walter, Sun Oil Co., Dr. 1861, Midland, Tex.
||Harrington, Lester Earl, Carter Oil Co., Lewistown, Mont.
||Havard, Charles Gentry, 705 E. Buffalo St., Ithaca, N. Y.
||Hawley, Arthur Scott, Union Oil Co. of Calif., 2700 F St., Bakersfield, Calif.
||Haworth, Charles Richard, Superior Oil Co., Evansville, Ind.
Haworth, Huntsman, consulting, 1491 Woodrow Ave., Wichita, Kan.
||Hayes, Raymond Beryl, 2451 Midway, Alexandria, La.
Henderson, LeRoy Cecil, British-American Oil Prod. Co., 508 Neil P. Anderson Bldg., Fort Worth, Tex.
||Hintze, Lehi F., Oregon State College, Corvallis, Ore.
||Holt, Charles Lee Roy, Jr., 1518 Barton Springs Rd., Austin 22, Tex.
||Horn, Paul Herbert, Sun Oil Co., Box 46, Amarillo, Tex.
||Hoyle, Lorraine Elizabeth, Pure Oil Co., Box 1398, Billings, Mont.
||Hughes, Clarence Wayne, Carter Oil Co., Denver, Colo.
||Huie, James Powell, Mene Grande Oil Co., C. A., Apt. 45, Barcelona, Venezuela, S. A.
||Hundley, Harland Brasher, Box 828, Alexandria, La.
||Irvin, William Carl, Texas Tech., Lubbock, Tex.
||Jacks, Howard Elmer, Lone Star Gas Co., Dallas, Tex.
||Jackson, Neil Arthur, independent, Box 244, Haskell, Okla.
||Jacques, Richard Dewey, Univ. of Michigan, Ann Arbor, Mich.
Jahns, Richard Henry, Calif. Inst. of Tech., Pasadena, Calif.
||Johnson, Charles Ripley, Jr., Richmond Petr. Co., Apt. 3631, Bogota, Colombia, S. A.
||Johnson, Ross Byron, U. S. Geol. Survey, Albuquerque, N. Mex.
||Katherman, Vance Edward, 258 Brighton Rd., Columbus, Ohio
||Keller, James Eugene, 318 E. Fourth St., Ottawa, Kan.
||Keyser, Joseph Edward, Woodley Petr. Co., Midland, Tex.
||Kibby, Theodore Arthur, Mene Grande Oil Co., Apt. 709, Caracas, Venezuela, S. A.
||King, William Sweitzer, 1580 S. University Blvd., Denver, Colo.
Kirkpatrick, Hobert Lewis, 445 Delaware Ave., Shreveport, La.
||Kite, James B., independent, 2818 First Natl. Bldg., Oklahoma City, Okla.
||Kolb, Charles R., Casilla 4040, Correo Central, Santiago, Chile, S. A.
||Krafve, William Carl, Magnolia Petr. Co., Mt. Vernon, Ill.
||Krinitzsky, Ellis Louis, U. S. W. E. S., Vicksburg, Miss.
||Kuehnert, Harold A., Phillips Petr. Co., 903 Old Natl. Bank Bldg., Evansville, Ind.

‖Kull, David J., Shell Oil Co., Inc., 1009 Central Bldg., Wichita, Kan.
‖Kuzmich, Rudolph Walter, 1231 Mulberry St., Mt. Carmel, Ill.
‖Lamb, Robert Reid, Atlantic Refg. Co., Box 520, Casper, Wyo.
‖Lastor, Jack Taylor, 1505 First Natl. Bldg., Oklahoma City, Okla.
‖Lebsack, Wayne, Box 308, Hays, Kan.
‖Leggat, Edward Ross, U. S. Geol. Survey, Plainview, Tex.
‖Levinson, Stuart A., Washington Univ., St. Louis, Mo.
Leyds, L. W., Raamweg 41, The Hague, Holland
‖Lipscomb, Vonno Rayford, Texas Pacific Coal & Oil Co., Fort Worth, Tex.
‖Lohman, Clarence, Jr., Box 1715, Univ. Sta., Austin, Tex.
‖Lohrentz, Donald Leslie, Rayflex Explor. Co., 6923 Snider Plaza, Dallas, Tex.
‖Long, George Ivan Wilbur, Continental Oil Co., Continental Oil Bldg., Denver, Colo.
‖Looney, Hugh Marvin, Atlantic Refg. Co., 910 Central Bldg., Wichita, Kan.
Loranger, Diane, Imperial Oil, Ltd., 300 Ninth Ave., W., Calgary, Alta., Canada
‖Lowe, Donald Paul, Atlantic Refg. Co., 110 N. Sixth St., Kingsville, Tex.
Lundy, Wilson Thomas, Freeport Sulphur Co., New York, N. Y.
‖Lupton, Dwight Keith, Dartmouth College, Hanover, N. H.
‖Lynn, John Reid, Carter Oil Co., Box 1153, Buffalo, Wyo.
‖Mack, Wayne Hamilton, Magnolia Petr. Co., Box 607, Lindsay, Okla.
‖MacLeod, George Marshall, The California Co., New Orleans, La.
Maddox, Walter H., Superior Oil Co. of Venezuela, Apt. 48, Caracas, Venezuela, S. A.
‖Magee, John Joseph, 2412 N. Dewey St., Oklahoma City, Okla.
‖Major, Rufus Orville, Box 958, Del Rio, Tex.
‖Malek-Aslani, Morad, 1423 Ford St., Golden, Colo.
‖Mann, Helen Louise, Continental Oil Co., Box 970, Casper, Wyo.
‖Marie, Earl Samuel, Tennessee Gas Transmission Co., Box 2511, Houston, Tex.
Marsh, Joseph Milton, Internatl. Petr. Co., Ltd., Talara, Peru, S. A.
‖Marsh, Robert Lyon, 323 Tenth St., Golden, Colo.
Marshall, Dan Landry, DeGolyer & MacNaughton, 1000 Continental Bldg., Dallas, Tex.
Mayes, John Wilmont, The Texas Co., Ardmore, Okla.
‖McCann, Thomas Paul, Trailer G-5, Vetsville, Boulder, Colo.
‖McCollum, Jack Hairston, 1120 Perrine Bldg., Oklahoma City, Okla.
‖McCracken, Guy Imbrie, Gulf Oil Corp., Box 661, Tulsa, Okla.
McCulloch, Robert Bruce, Geophoto Services, 305 E. &. C. Bldg., Denver, Colo.
‖McFarland, Albert Kenneth, The Carter Oil Co., Box 120, Denver, Colo.
‖McFarland, Gloria June, The American Association of Petroleum Geologists, Box 979, Tulsa, Okla.
‖McGinley, John Andrew, Skelly Oil Co., First Natl. Bank Bldg., Oklahoma City, Okla.
‖McGirk, Donald Dea, Texas Petr. Co., Apt. 267, Caracas, Venezuela, S. A.
‖McKay, Edward Joseph, U. S. Geol. Survey, Box 372, Grand Junction, Colo.
‖McKee, Edith Merritt, Arabian-American Oil Co., Dhahran, Saudi Arabia
‖McMurry, James Rush, The Texas Co., Box 600, Wichita Falls, Tex.
McWilliams, William Kennon, Jr., The Superior Oil Co., New Orleans, La.
‖Merriam, Daniel Francis, 1728 Massachusetts St., Lawrence, Kan.
‖Milne, James Fraser, Imperial Oil Co., Ltd., Edmonton, Alta., Canada
Minturn, Louis Walcott, Alcoa Mining Co., Bauxite, Ark.
‖Moody, Herbert H., Rayflex Explor. Co., Dallas, Tex.
Moore, Hastings, Danciger Oil & Refg. Co., Henderson, Tex.
‖Moore, Quentin Morrow, General Petr. Corp., Paso Robles, Calif.
‖Moore, Watson Lee, Petty Geophys. Engr. Co., 1205 Hunt Bldg., Tulsa, Okla.
Moore, Wayne Elden, Cornell Univ., Ithaca, N. Y.
Morehouse, Richard Elliott, Carter Oil Co., Box 428, Lander, Wyo.
Morgan, Charles Boyd, Sohio Petr. Co., Abilene, Tex.
‖Mosher, Harold Charles, Sohio Petr. Co., Box 359, Casper, Wyo.
‖Moss, Muriel Ellen, Southern Methodist Univ., Dallas, Tex.
Moyar, Robert E., Tropical Oil Co., El Centro, Colombia, S. A.
‖Mudge, Melville Rhodes, U. S. Geol. Survey, Manhattan, Kan.
Mundorff, Maurice J., U. S. Geol. Survey, Tacoma, Wash.
‖Murchison, John William, Jr., Seismic Explor., Inc., Galveston, Tex.
‖Murphy, Edward Gilpin, Stanolind Oil & Gas Co., Winslow, Ariz.
‖Murphy, John A., Continental Oil Co., Ponca City, Okla.
‖Myron, Kenneth Eaton, The Texas Co., Box 327, Taft, Calif.
‖Naff, John Davis, Oklahoma A. & M. College, Stillwater, Okla.
‖Needham, Charles Nelson, General Geophys. Co., Douglas, Wyo.
Nelson, Clemens Arvid, Univ. of California, Los Angeles, Calif.

‖Ogden, Park Greenman, Jr., Stanolind Oil & Gas Co., Box 1518, Lake Charles, La.
Oliver, William Benjamin, Humble Oil & Refg. Co., Floresville, Tex.
‖Olson, Frank Hugh, Phillips Petr. Co., Box 791, Midland, Tex.
‖Ortel, Walter Hewitt, Richmond Explor. Co., Apt. 93, Maracaibo, Venezuela, S. A.
Ortynski, Hilary Igor, c/o S. N. Repal, 34 B-d, Saint Saens, Algeria
‖Park, William Gray, 1185 Ninth St., Golden, Colo.
‖Parker, Ben Hutchinson, Jr. Box 508, Golden, Colo.
‖Parker, Margaret Ann, Illinois Geol. Survey, Urbana, Ill.
‖Pearson, Bruce Terrill, Seaboard Oil Co., Box 601, Corpus Christi, Tex.
Pease, Everett Wilfred, Barnsdall Oil Co., Oildale, Calif.
Peeples, Eugene Murrell, Jr., Edson Petr. Co., 1537 Esperson Bldg., Houston, Tex.
Penner, David George, Texaco Explor. Co., 809 Fourth St. West, Calgary, Alta., Canada
‖Percy, Calvin Greer, Humble Oil & Refg. Co., Box 522, Ozona, Tex.
‖Perry, Ashton Turner, Jr., 200 Wilkinson-Foster Bldg., Midland, Tex.
‖Petersen, Richard Gray, U. S. Geol. Survey, Plant City, Fla.
Peterson, Morris Albert, Union Prod. Co., Box 1422, Monroe, La.
‖Phillips, B. Cochran, Phillips Petr. Co., Box 1381, Corpus Christi, Tex.
Player, John, Jr., The Atlantic Refg. Co., 830 Kennedy Bldg., Tulsa, Okla.
‖Pluta, Joseph Stanley, Standard Oil Co. of Texas, Box 1660, Midland, Tex.
Ponte-Rodriguez, Carlos Jose, Creole Petr. Corp., Apt. 889, Caracas, Venezuela, S. A.
‖Pope, David E., Union Prod. Co., Box 206, Kenner, La.
Pounder, Douglas Allan, The California Standard Co., 304 Examiner Bldg., Calgary, Alta., Canada
‖Prescher, William Francis, Sun Oil Co., Box 1166, Casper, Wyo.
‖Prickett, Walter Thomas, 2528 Wilkinson, Fort Worth, Tex.
Quinn, Howard Edmund, Texas College of Mines & Met., El Paso, Tex.
‖Ralston, John Stanley, Jr., Sharples Oil Corp., Denver, Colo.
‖Rantala, Raymond Henry, Pure Oil Co., Box 2107, Fort Worth, Tex.
‖Read, John Leighton, Jr., 2100 Cornell St., Palo Alto, Calif.
‖Reed, Hugo Miller, 1621 Sixteenth St., Lubbock, Tex.
‖Reid, John William, The California Co., Vernal, Utah
‖Requist, Norris N., Magnolia Petr. Co., Box 1828, Oklahoma City, Okla.
Reynolds, Howard William, Jr., consulting, 3110-A Riverside Dr., Burbank, Calif.
‖Richardson, Colonel Adams, Jr., Carter Oil Co., Oklahoma City, Okla.
‖Riddle, Edd, Jr., Texas Pacific Coal & Oil Co., Box 254, Sheridan, Wyo.
Riggins, Leslie Burnham, Jr., Portable Drilling Corp., Seminole, Okla.
‖Ripple, Alfred Louis, 1816 Nueces St., Austin, Tex.
‖Riveroll, David D., The Texas Co., Rm. 715, 939 S. Broadway, Los Angeles, Calif.
‖Robinson, Gene R., Union Prod. Co., Box 1407, Shreveport, La.
Robitshek, Melvin F., Phillips Petr. Co., Bartlesville, Okla.
‖Roth, Ernest E., Columbia Engr. Corp., 120 E. Forty-first St., New York, N. Y.
‖Rutledge, Virginia Mae, Phillips Petr. Co., Bartlesville, Okla.
‖Ruwwe, Ralph Walter, 2435 Shadybrook Lane, Wichita, Kan.
‖Ryan, Edward Stone, 204 Norman Ct., Greenwood Apts., Trenton, N. J.
Rylands, Albert Thomas, Shell Oil Co., Inc., Corpus Christi, Tex.
‖Salisbury, Gerald P., Union Oil Co. of Calif., Box 298, Cut Bank, Mont.
Sams, Robert Lee, The Texas Co., Box 252, New Orleans, La.
‖Saunders, James Marshall, Tide Water Assoc. Oil Co., Box 233, Green River, Utah
‖Schiemenz, Albert Martin, Jr., Phillips Petr. Co., Box 1729, Shreveport, La.
‖Schwab, Robert Charles, Box 549, Golden, Colo.
Setzer, Francis Marion, Stanolind Oil & Gas Co., Box 3092, Houston, Tex.
Shell, Horace Edward, Superior Oil Co., Stottler, Alta., Canada
‖Sherrod, Harold Wesley, Stanolind Oil & Gas Co., Box 1540, Midland, Tex.
Shouldice, James Robert, Suite 1, 1026 Twelfth Ave., West, Calgary, Alta., Canada
‖Shuler, Edward Hooper, Pacific Western Oil Corp., Los Angeles, Calif.
‖Sims, Frank Chambers, Continental Oil Co., Box 970, Casper, Wyo.
Sims, James Nathan, Phillips Petr. Co., Houston, Tex.
‖Skinner, John William, Jr., Box 1267, College Station, Tex.
‖Smart, Robert Russell, General Petr. Corp., Vernal, Utah
‖Smith, Avery Edward, Box 206, Wilson Center, Norman, Okla.
‖Smith, Jimmie C., Jr., Phillips Petr. Co., Bartlesville, Okla.
‖Smith, Russell, The Pure Oil Co., Olney, Ill.
‖Soady, Jean Elizabeth, 2210 Thirty-eighth St., Rock Island, Ill.
‖Spain, David Stevenson, 4210 W. Sixty-ninth St., Mission, Kan.
Speer, John Hill, Univ. of Oklahoma, Norman, Okla.

‖Starr, A. G., Humble Oil & Refg. Co., 1110 Craig, Corpus Christi, Tex.
‖Steele, Guy Merwin, Jr., Oklahoma Geol. Survey, Faculty Exch., Norman, Okla.
‖Stewart, Simeon Brooks, Sohio Petr. Co., Houston, Tex.
Stokley, John Allen, Univ. of Kentucky, Lexington, Ky.
Stowell, Colles Coe, Kerr-McGee Oil Industries, Inc., 717 Ardis Bldg., Shreveport, La.
‖Strong, Royal Bernard, Carter Oil Co., Box 161, Grand Rapids, Mich.
‖Sturz, Charles Eugene, Tide Water Assoc. Oil Co., 79 New Montgomery, San Francisco, Calif.
‖Summers, George E., Jr., Pure Oil Co., Box 1398, Billings, Mont.
‖Sun, Ming-Shan, Box 7150, Louisiana State Univ., Baton Rouge, La.
Tate, Garvin Louis, Humble Oil & Refg. Co., Box 100, Grand Isle, La.
Taylor, Paul Byron, Syria Petr. Co., Aleppo, Syria
‖Tellington, Wentworth J., Bear Oil Co., Ltd., 9616 One-hundred-one-A Ave., Edmonton, Alta., Canada
Terry, Lyon F, The Chase Natl. Bank, 18 Pine St., New York, N. Y.
‖Thompson, Warren Charles, Scripps Inst. of Oceanography, La Jolla, Calif.
‖Throop, William Hilliard, 807 Sixteenth St., Golden, Colo.
‖Troster, John Gooch, 8838 S. Nogal Ave., Whittier, Calif.
‖Umbach, Elmer Dean, Atlantic Refg. Co., Box 520, Casper, Wyo.
Vandeventer, Ray Bloss, Petty Geophys. Engr. Co., 1205 Hunt Bldg., Tulsa, Okla.
‖Van Sickle, Donald McKellar, U. S. Geol. Survey, San Marino, Calif.
Vaughan, Joseph Barnett, 450 Crestview Dr., Henderson, Ky.
‖Velotta, George William, Phillips Petr. Co., Box 152, Shawnee, Okla.
‖Veroda, Victor Joye, Republic Natural Gas Co., 1155 First Natl. Bank Bldg., Oklahoma City, Okla.
Waid, John Bricker, Humble Oil & Refg. Co., Tallahassee, Fla.
‖Walker, Doris Lula, Ohio Oil Co., Box 3128, Houston, Tex.
Warner, Douglas Frank, Seismograph Service Corp., Box 1590, Tulsa, Okla.
‖Warren, Lewis Coy, Stanolind Oil & Gas Co., Box 1540, Midland, Tex.
‖Warren, Virginia Ada, Standard Oil Co. of Calif., Paso Robles, Calif.
‖Wassall, Harry William, III, Shell Oil Co., Inc., Box 2099, Houston, Tex.
‖Wasselhoeft, Robert, Jr., 910 E. Elmwood Dr., Abilene, Tex.
Webb, Robert Wallace, Univ. of Calif., Santa Barbara, Calif.
‖Weeth, Charles Andrew, Humble Oil & Refg. Co., 812 Humble Bldg., Houston, Tex.
‖Weigl, Karl Edward, Shell Oil Co., Inc., New Orleans, La.
‖Wells, Lewis Franklin, 154 S. Fourth East, Pleasant Grove, Utah
‖West, Warren Earl, Jr., Continental Oil Co., Box 970, Casper, Wyo.
‖Whaley, William Joseph, Jr., Humble Oil & Refg. Co., Box 2180, Houston, Tex.
Wheeler, Harry Eugene, Univ. of Washington, Seattle, Wash.
Whitworth, Virgil Lee, Drilling & Explor. Co., Inc., 600 Continental Bldg., Dallas, Tex.
‖Williams, George Quigley, Cornell Univ., Ithaca, N. Y.
‖Williams, Louis Aubrey, Sun Oil Co., Box 1861, Midland, Tex.
‖Williamson, Joseph Dunstan Mitchell, c/o Paul B. Williamson, 501 Whitney Bldg., New Orleans, La.
‖Willis, Robert Eugene, Jr., Magnolia Petr. Co., Box 56, Houston, Tex.
‖Wilson, Joseph Cox, Ohio Oil Co., Wichita, Kan.
Wilson, Leonard Richard, Univ. of Massachusetts, Amherst, Mass.
‖Wood, Kenneth Alvin, Olney, Tex.
‖Wright, Jerome J., The California Co., Box 780, Denver, Colo.
‖Zeller, Edward J., Rm. 13, Science Hall, Univ. of Wisconsin, Madison, Wis.

SECOND LIST

‖Albers, Charles Clarence, Stanolind Oil & Gas Co., Box 3092, Houston, Tex.
‖Allen, Paul H., Jr., Union Producing Co., Box 711, Beeville, Tex.
‖Andrako, Albert Francis, Gulf Oil Corp., Box 1111, Seminole, Okla.
‖Arbuckle, Walter Kay, British-American Oil Prod. Co., Box 65, Taft, Tex.
‖Babisak, Julius, Atlantic Refg. Co., Box 895, Lake Charles, La.
‖Bagwell, James Edward, 155 Fore St., Sulphur Springs, Tex.
‖Baker, Maylon Sumner, Jr., Paleontological Lab., Box 51, Midland, Tex.
Barnes, Frank Charles, New Mexico Oil Conservation Comm., Box 871, Santa Fe, N. Mex.
‖Barnhart, Perry E., Jr., Cities Service Oil Co., Box 2368, Wichita Falls, Tex.
Beardmore, Heber Knox, Jr., Beadmore Drilling Co., 603 Petroleum Bldg., Wichita, Kan.
‖Benke, May Lee, The Texas Co., Houston, Tex.
‖Blake, Oliver Duncan, Ohio Geol. Survey, Columbus, Ohio
‖Bogart, Vera Jo, Apt. B-5, Winlen Apts., Enid, Okla.
Bonillas, Ygnacio, Richmond Explor. Co., Apt. 93, Maracaibo, Venezuela, S. A.
‖Brantly, Mims McGehee, Drilling & Explor. Co., Box 182, Abilene, Tex.
‖Bryan, Robert Calvin, 904 S. Pickard, Norman, Okla.

Buck, Harry F., Anderson-Prichard Oil Corp., Oklahoma City, Okla.
Buckthal, Walter Paul, The Texas Co., Box 1270, Midland, Tex.
Budd, Harrell, Jr., 6210 Reiger Ave., Dallas, Tex.
Buford, Thomas Bernard, U. S. Geol. Survey, Baton Rouge, La.
Burke, Thomas Milton, Rt. 3, Elgin, Tex.
Burroughs, Billy Bob, Arkansas Fuel Oil Co., Box 1734, Shreveport, La.
Caffey, Earnest Clifton, Standard Oil Co. of Texas, Box 538, Dallas, Tex.
Campbell, Gaylord Leon, British-American Oil Co., Oklahoma City, Okla.
Carney, James Bernard, The California Co., Box 890, Lexington, Ky.
Carter, David A., Colorado Fuel & Iron Corp., Pueblo, Colo.
Chaddock, Dean, Phillips Petr. Co., Midland, Tex.
Chestant, Lester Aubry, Jr., 4137 Palmyra St., New Orleans, La.
Chenot, George Richard, Standard Oil Co. of Texas, Box 538, Dallas, Tex.
Chisholm, Earl James, 1412 Polk St., Wichita Falls, Tex.
Chombart, Louis G., Schlumberger Well Surveying Corp., Box 1034, Wichita, Kan.
Chubb, Lewis Orr, Rogers-Ray, Inc., Houston, Tex.
Clement, Edmund Allen, Jr., Box 724, Wilson Center, Norman, Okla.
Clevenger, Paul Raphael, Geophysical Service Inc., Box 26, Leeds, N. Dak.
Cobb, William Henry, Jr., Shell Oil Co., Inc., Box 1509, Midland, Tex.
Cornell, Drew, consulting, Box 1000, Lafayette, La.
Cowdrey, Joseph Lee, Amerada Petr. Corp., Box 2026, Tyler, Tex.
Cox, J. B., 2800 Trice Ave., Waco, Tex.
Danielson, Daryl Arthur, The Texas Co., Box 2523, West Jackson, Miss.
Della-Rose, Frank, Shell Oil Co., Inc., Ventura, Calif.
Dennis, James E., Standard Oil Co. of Texas, Box 1660, Midland, Tex.
Devine, William Hardeman, Sun Oil Co., Box 465, Pharr, Tex.
Dolman, Jack Allan, Phillips Petr. Co., Bartlesville, Okla.
Douglass, H. Marvin, 202 N. Country Club Dr., Tulsa, Okla.
Dunbar, Donald George, Jr., 3115 Benelva Dr., Austin, Tex.
Dunham, Robert Jacob, Univ. of Oklahoma, Box 671, W.W.C., Norman, Okla.
Easterly, Herman, Jr., Exploration Service Co., Box 305, Haskell, Tex.
Eatherly, Samuel Parks, 1623 Tenth, Lubbock, Tex.
Ebright, John Richard, Pennsylvania Topographic & Geologic Survey, Butler, Pa.
Edwards, Jack Walton, Apache Explor. Co., Houston, Tex.
Elliott, Edna Jean, Stanolind Oil & Gas Co., Box 1540, Midland, Tex.
Esmond, Thomas Marlon, c/o R. C. Lipscomb, San Antonio, Tex.
Evens, Joseph Horne, Phillips Petr. Co., Box 380, Pauls Valley, Okla.
Faulk, Niles Richard, The California Co., Meridian, Miss.
Forrer, Martin, Texas Petr. Co., Apt. 516, Maracaibo, Venezuela, S. A.
Galny, Gerhard H., Jr., Continental Oil Co., Wichita Falls, Tex.
Girard, Cecil Meshew, The California Co., New Orleans, La.
Goltz, Eugene M., Abilene Sample Log Service, Abilene, Tex.
Habicht, Konrad, B.P.M. (Shell), Schaffhausen, Switzerland
Hamilton, Daniel Kirk, Univ. of Kentucky, Lexington, Ky.
Hammond, Robert Wesley, Anderson-Prichard Oil Co., Oklahoma City, Okla.
Harder, Richard Russell, The Geotechnical Service Corp., 3712 Haggar Dr., Dallas, Tex.
Harris, D. B., Seismograph Service Corp., Box 1590, Tulsa, Okla.
Harris, Jay J., Stanolind Oil & Gas Co., Box 335, Albuquerque, N. Mex.
Hartman, James Kent, Los Nietos Co., Box 1450, Midland, Tex.
Harvey, Lyle H., c/o John W. Mecom, 2906 Gulf Bldg., Houston, Tex.
Haskins, Paul Edwin, Mid-Continent Petr. Corp., Box 830, Midland, Tex.
Henry, William Waldo, MSC Trailer C-17, E. Lansing, Mich.
Homan, William Leftwich, Republic Explor. Co., Box 381, Midland, Tex.
Howard, Thomas Scott, American Republics Corp., Box 329, San Angelo, Tex.
Howe, Wallace B., Lindley Hall, Univ. of Kansas, Lawrence, Kan.
Hunt, Louis Leon, 2116 Twentieth St., Lubbock, Tex.
Japp, Henry G., Stanolind Oil & Gas Co., 429 First Natl. Bank Bldg., Wichita, Kan.
Johnson, Earle Winston, General Geophys. Co., 2514 Gulf Bldg., Houston, Tex.
Johnson, Edward John, Magnolia Petr. Co., Box 633, Midland, Tex.
Johnson, Russell V., Jr., Mack Oil Co., McCasland Bldg., Duncan, Okla.
Johnston, Charles W., Jr., Gulf Oil Corp., Box 808, Seminole, Okla.
Keplinger, John Leonard, Atlantic Refg. Co., 910 Central Bldg., Wichita, Kan.
Kern, Roy L., 3315 Fairfield Ave., Shreveport, La.
Kidd, Stuart James, Amerada Petr. Corp., 229 Blow Bldg., Calgary, Atla., Canada
Killough, Louis Linn, Humble Oil & Refg. Co., Baytown, Tex.

||Kincaid, John Vernon, Rexray Drilling Co., McKinney, Tex.
Klemme, Daniel Norman, The Hancock Oil Co. of Calif., Los Angeles, Calif.
Kline, Loren Effenger, Jr., 215 N. Twenty-third Ave., Hattiesburg, Miss.
Kurk, Edwin Herman, Seismograph Service Corp., Oklahoma City, Okla.
||Lammons, James Monroe, 1140 N. Emporia Ave., Wichita, Kan.
||Lane, Charles Wallace, U. S. Geol. Survey, Iowa City, Iowa
||Langen, Raymond Eugene, Carter Oil Co., Box 438, Manhattan, Kan.
Lerke, Boris, V., consulting, 3600 Elmwood Dr., Wichita, Kan.
||Link, George Edward, Cooperative Refinery Assn., 914 Central Bldg., Wichita, Kan.
||Lombardi, Leonard Volk, Stanford University, Stanford, Calif.
Lytle, Frank Callen, Houston Oil Co. of Texas, 914 Giddens-Lane Bldg., Shreveport, La.
||Mackey, Earl Thomas, Copetco Corp., 1707 Second Natl. Bank Bldg., Houston, Tex.
||Martin, Jack Philip, Shell Oil Co., Inc., Dr. 5157, Drew Sta., Lake Charles, La.
Maxwell, James Melvin, Shell Oil Co., Inc., Mayo Bldg., Tulsa, Okla.
||McClure, Leo Junior, Humble Oil & Refg. Co., Thibodaux, La.
||McCutchen, Edgar Owens, Western Geophys. Co., Box 478, Lamesa, Tex.
||McLean, Clarence Marvin, III, Atlantic Refg. Co., Box 1346, Houston, Tex.
McWilliams, John Ford, Union Prod. Co., Box 1020, Jackson, Miss.
Meacham, Jim Clarence, Humble Oil & Refg. Co., Box 1271, Corpus Christi, Tex.
||Merrell, Garland P., Jr., Pipeline Service Co., Seminole, Okla.
Milton, Arthur Alvern, Seismograph Service Corp., Box 1590, Tulsa, Okla.
||Mincher, Jack Richard, Humble Oil & Refg. Co., 1110 Craig Ave., Corpus Christi, Tex.
Montgomery, Paul, independent, 328 Stevenson St., Lafayette, La.
||Murray, Theodore Robert, Cities Service Oil Co., Box 2368, Wichita Falls, Tex.
Newsom, Young Beverly, Gulf Oil Corp., Fort Worth, Tex.
||Newton, Ralph James, Standard Oil Co. of Calif., Box 876, Rio Vista, Calif.
||Nixon, Achilles Harry, 1012 Burnett St., Fort Worth, Tex.
||Norville, Glen Crosby, c/o Glen S. Norville, 1019 Tradesman Natl. Bank, Oklahoma City, Okla.
||O'Connell, Everett M., Cooperative Refinery Assn., 914 Central Bldg., Wichita, Kan.
||Parrish, James Hooks, Pure Oil Co., Box 671, Midland, Tex.
Patton, Howard Lewis, The California Co., Denver, Colo.
||Perry, Wimberly Raymond, Mid-Continent Petr. Corp., Midland, Tex.
||Petersen, Francis Alfred, The California Co., 1818 Canal Bldg., New Orleans, La.
||Pinney, Earl Tannert, The Texas Co., Houston, Tex.
||Plank, Robert Forrest, Carter Oil Co., Bartlesville, Okla.
Prough, Richard Grant, Union Prod. Co., Houston, Tex.
||Rector, Don W., 221 University Place, Norman, Okla.
||Rees, Rhys W., Shell Oil Co., Inc., Box 1509, Midland, Tex.
||Rezak, Richard, St. Lawrence Univ., Canton, N. Y.
||Richey, Wilbur Eddy, 603 S. Ennis, Bryan, Tex.
||Ries, Homer U., 933 Mississippi St., Lawrence, Kan.
Ringenberg, Lester J., Carter Oil Co., Box 161, Grand Rapids, Mich.
||Rodgers, Elton Ernest, Jr., 1611-A College Ave., Lubbock, Tex.
||Rothrock, David Paul, Carter Oil Co., Box 120, Denver, Colo.
||Rue, Edward Evans, Box 175, Danville, Ky.
||Sartor, Charles Lane, Barnsdall Oil Co., Shreveport, La.
||Schlax, William Nicholas, Jr., Superior Oil Co., 313 Sill Bldg., Bakersfield, Calif.
||Shifflett, Frances Elaine, Standard Oil Co., of Texas, Box 1249, Houston, Tex.
||Sides, Jerry Franklin, Superior Oil Co., Midland, Tex.
Slagle, Walter James, Shell Oil Co., Inc., 965 First Natl. Bank Bldg., Oklahoma City, Okla.
Sturgeon, Galen Howard, Shell Oil Co., Inc., Box 357, Grand Junction, Colo.
||Sullivan, Daniel Francis, Continental Oil Co., Bakersfield, Calif.
Tafur-Hernandez, Isaac Antonio, Bureau of Waters & Irrigation, Ministerio de Fomento, Lima, Peru, S. A.
||Terry, Joe Lee, Houston Oil Co., Houston, Tex.
||Thomas, Billy Dean, 907 Shawnee St., Graham, Tex.
Turner, Gregory Larkin, The Pure Oil Co., Box 29, Tyler, Tex.
||Turner, Marion Orville, Apt. 2, 614 Glazebrook, Corpus Christi, Tex.
||Twining, John Theodore, Bureau of Economic Geol., Univ. of Texas, Austin, Tex.
||Tyler, Albert Norton, 945 Missouri, Lawrence, Kan.
Vauclain, Samuel Matthews, III, Sun Oil Co., Jackson, Miss.
||Waggoner, Ralph Edward, independent, Box 3054, Wichita Falls, Tex.
||Watchous, Robert Wayne, 2144 Exchange, Wichita, Kan.
West, Thomas Marshall, Magnolia Petr. Co., Box 633, Midland, Tex.
||Young, Wilfred Ray, 2408 Ave. P, Lubbock, Tex.

REPORT OF NOMINATING COMMITTEE

Los Angeles, California
July 22, 1949

To the Executive Committee
C. W. Tomlinson, *chairman*

The nominating committee respectfully submits the following list of candidates for officers of the Association for the coming year.

For President—CLARENCE L. MOODY, Ohio Oil Company, Shreveport, Louisiana
THERON WASSON, Pure Oil Company, Chicago, Illinois

For Vice-President—JOHN EMERY ADAMS, Standard Oil Co. of Texas, Midland, Tex.
E. W. KRAMPERT, consulting, Casper, Wyoming

For Secretary-Treasurer—W. J. HILSEWECK, Republic Natural Gas Co., Dallas, Tex.
EDWARD F. SHEA, Stanolind Oil and Gas Company, Tulsa, Oklahoma

For Editor—ALFRED H. BELL, Illinois Geological Survey, Urbana, Illinois

E. B. NOBLE, *chairman*
MONROE G. CHENEY LYNN K. LEE
CHARLES J. HARES W. C. SPOONER

Note.—Photographs and biographies of candidates will be published in the November *Bulletin*, provided they are received at Association headquarters not later than September 29.

A.A.P.G. REGIONAL MEETING, BILOXI, MISSISSIPPI, OCTOBER 12–14, 1949

A regional meeting of the Association will be held at the Buena Vista Hotel, Biloxi, Mississippi, October 12–14, 1949. The following six southeastern geological societies are the co-hosts.

East Texas Geological Society
Mississippi Geological Society
New Orleans Geological Society
South Louisiana Geological Society
Shreveport Geological Society
Southeastern Geological Society

Several geophysical papers of interest to the geologists will be presented by the Ark-La-Tex Geophysical Society.

Hotel-room reservation cards have been mailed to all members and an early reply will be appreciated by the committee.

Tentatively, the program consists of a pre-convention symposium on the work in the Gulf Coast of the Cenozoic and Mesozoic subcommittees of the geologic names and correlations committee. The technical program will be shared equally by the participating geological societies. Each group will present papers dealing with significant problems of their areas.

A series of air-borne excursions over the Mississippi Delta and including aerial visits to the water operations are contemplated.

The convention committee for this meeting consists of the following.

Chairman: T. H. PHILPOTT, The Carter Oil Company, Box 1739, Shreveport, Louisiana.
Hotels: M. N. BROUGHTON, The Texas Company, Box 252, New Orleans, Louisiana.
Publication: L. R. McFARLAND, Magnolia Petroleum Company, 508 Millsaps Building, Jackson, Mississippi.
Publicity: HASTINGS MOORE, Danciger Oil and Refining Company, 207 Webster Walk, Henderson, Texas.

Technical equipment: G. E. MURRAY, Louisiana State University, Baton Rouge, Louisiana.
B. M. CHOATE, Atlantic Refining Company, Jackson, Mississippi.
General: F. M. SCHALL, Big Chief Drilling Company, Shreveport, Louisiana.
W. B. NEILL, Stanolind Oil and Gas Company, Lake Charles, Louisiana.
J. L. MARTIN, JR., Sinclair-Wyoming Oil Company, Jackson, Mississippi.
Geophysical papers: H. M. BUCHNER, The Carter Oil Company, Drawer 1739, Shreveport, Louisiana.
L. F. FISCHER, Sohio Petroleum Company, Lafayette, Louisiana.
G. E. WAGONER, The Carter Oil Company, Box 1739, Shreveport, Louisiana.
Field excursions: D. E. NEWLAND, Magnolia Petroleum Company, Box 872, Lake Charles, Louisiana.

TECHNICAL PROGRAM

REGIONAL PAPERS

Facies Changes in Gulf Cretaceous Beds in Mississippi, by Tom McGlothlin, consultant.
Petroleum Exploration in Eastern Arkansas, by C. A. Renfroe, Arkansas Resources and Development Commission.
Surface and Subsurface Correlation of the Wilcox Formation, by D. A. Robertson, C. M. Swartz, and A. H. Trowbridge, Centenary College.
Interior Salt Domes of East Texas, by G. C. Clark, Stanolind Oil and Gas Company.
Control of Petroleum Accumulation by Sedimentary Facies in South Louisiana, by Max Bornhauser, Continental Oil Company.
Geosynclinal Sedimentation in Central Gulf Region of United States, by Grover E. Murray, Louisiana State University.
Preliminary Report on Buried Pre-Mesozoic Rocks in Florida and Adjacent States, by Paul L. Applin and Charles Milton, United States Geological Survey.
Stratigraphic, Structural, and Correlation Studies of Florida Tertiary, by Robert O. Vernon, Florida Geological Survey.
Structure of South Louisiana Deep Seated Salt Domes, by W. E. Wallace, Sohio Petroleum Company.

FIELD PAPERS

Merigale-Paul Field, Wood County, Texas, by Hastings Moore, Danciger Oil and Refining Company.
Blackfoot Field, Anderson County, Texas, by D. O. Branson, Stanolind Oil and Gas Company.
Brookhaven Field, Lincoln County, Mississippi, Robert Womack, Jr., The California Company.
The LaGrange Oil Field, Adams County, Mississippi, by M. W. Sherwin, Sohio Petroleum Company.
Cairo Field, Union County, Arkansas, by L. A. Goebel, The Carter Oil Company.

MISCELLANEOUS PAPERS

Occurrence of the Genus Choffatella in Wells in South Florida and at Other Localities, by Louise Jordan and Esther R. Applin, Sun Oil Company and United States Geological Survey.
A New Method of Local and Regional Correlation Using the Resistivity Value from Electrical Logs by A. Claudet, Schlumberger Well Surveying Corporation.
Drilling Difficulties in North Florida and South Georgia, by Don J. Munroe, Sun Oil Company.

GEOPHYSICAL PAPERS

Geophysical "Case History" of the Mississippi Salt Dome Basin, by L. L. Nettleton, Gravity Meter Exploration Company.
The Part Helicopters are Playing in Geophysical Exploration, by E. E. Gustafson, Bell Aircraft.
Off-Shore Seismic Operations, by L. F. Guseman, American Exploration Company.
The Oceanographic and Meteorological Aspects of Geophysical Prospecting, by Alfred H. Glenn and Charles C. Bates, consultants.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 33, NO. 9 (SEPTEMBER, 1949), PP. 1637–1638, 1 FIG

MEMORIAL

ALFRED SENN

(1899–1949)

On the 1st of July, Alfred Seen would have celebrated his 50th birthday had he not succumbed on the 29th of January from the after-effects of a minor operation when seeking strength in his beloved Grison Mountains of Switzerland. He left behind his devoted wife and their two daughters.

Among his many friends are geologists in all parts of the world who deplore the untimely loss of a colleague whose dutiful attitude toward their science promised many more valuable contributions.

Following preliminary studies at the universities of Neuchatel and Paris, it was at the alma mater of his hometown Basel where Alfred Senn finally matriculated for the study of natural sciences with preference for geology. Under the inspiring guidance of Professor A. Buxtorf he gained promotion with an excellent thesis on the geology of the area between Mendrisio and Varese at the southern foot of the Alps and then, heeding his teacher's advice, he started with the detailed geological mapping of a part of the block-faulted Jura Mountains, a task he had just completed when death called him.

Like many young Swiss who can not make a living from their vocation in their home country, so poor in mineral resources and so full of geologists, Alfred Senn followed the footsteps of the pioneer among Swiss petroleum geologists, Professor Carl Schmidt, and accepted employment with the North Venezuelan Petroleum Company, Ltd. In the years from 1927 to 1932 he, together with others, explored a large part of the geologically little known central and eastern Falcón in Venezuela. His keen interest in exploration work, especially his unflagging energy in applying paleontology to stratigraphic problems, was instrumental in securing for the first time positive results in the zoning of Tertiary sediments of Venezuela with the aid of smaller foraminifera. True to his training, he also made use of the remaining fossils, thereby succeeding in correlation of sediments of vastly different facies.

On termination of his task, Alfred Senn joined the Compagnie Francaise des Petroles to carry out investigations in Algeria and Marocco, where he found stratigraphic conditions in many respects like those in Venezuela. In a publication dealing with his findings in these two countries, he especially stressed the application of orbitoids for purposes of zoning.

In 1937 one found Alfred Senn again in the Caribbean region but this time engaged in a very detailed geological survey of the island of Barbados on behalf of the British Union Oil Company. During the war the Colonial Welfare and Development made use of Senn's knowledge for water supply and other geotechnical problems. His report on "Geological Investigations of the Groundwater Resources of Barbados" is an outstanding contribution to the literature of West Indian water supply and of great value to the island of Barbados. In his paper dealing with the "Paleogene of Barbados and Its Bearing on History and Structure of Antillean Caribbean Region" (*Bull. A.A.P.G.*, Vol. 24, 1940) he submitted the first modern report on the island's geology. Publications of T. W. Vaughan, J. W. Wells, and M. de Cizancourt deal with material collected by Senn in Barbados. In a subsequent paper on "The Geology of Barbados and the Morphogenesis of the Neighbouring Submarine Topography" (*Ec. Geol. Helv.*, Vol. 40, 1948) he discussed the nature and depositional environment of the Oceanic formation and tried to fit the geological history of Barbados into that of the Antillean arch.

The commercially engaged petroleum geologist is generally left with little time for

scientific publications; nay, he is often discouraged from contemplating such. All the more it is to the credit of Alfred Senn that he spent much of his spare time in paleontological investigations, study of literature, and preparations of graphs which allowed him to make contributions to our science.

But science alone could not satisfy his truth-seeking and art-loving mind, coupled with a longing to improve his skill in mountain climbing and skiing in order to maintain a well trained body. It was, however, in the field of exploration and in the camp where he showed his true mettle, for where men are forced to live and work together under adverse conditions, their inherent characters reveal themselves. Under such circumstances there was no better comrade than Alfred Senn. He was a joyful, helpful, open-hearted companion, never dismayed by the vagaries of nature. After days of tracking through rain-soaked tropical forests with pack mules and the bare necessities for camping, he still was prepared to carry his load if it meant reaching a geologically unexplored region where no pack animals could follow. He would discuss the daily problems when stretched in his hammock, slung between two trees, and would not lose his humor when a nocturnal downpour forced him to hide field book and maps under his body to save them from being soaked. It is in such moments when men at work come to talk of their innermost feelings and it was then that one found Alfred Senn to be a sensitive thinker, a deeply religious man whose interest in the welfare of his family and in a brighter future of mankind was his ever present concern.

ALFRED SENN

H. G. KUGLER

Caracas, Venezuela
August 22, 1949

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 33, NO. 9 (SEPTEMBER, 1949), PP. 1639-1642

AT HOME AND ABROAD

NEWS OF THE PROFESSION

The 62d annual meeting of the Geological Society of America will be held at El Paso, Texas, November 10–12. The Cortez is headquarters.

The Pacific Section of the Association meets at the Ambassador Hotel, Los Angeles, California, November 17–19.

WARREN CALVERT has moved from Oklahoma City, Oklahoma, to Fairfield, Illinois, where he is associated with Tuley and Carter, drilling contractors.

K. A. OLSON has moved from Denver, Colorado, to Calgary, Alberta, Canada. He is in the newly opened offce of the Phillips Petroleum Company in the Greyhound Building, Seventh Avenue and First Street, West.

PHILIP R. ALLIN is with the Gulf Refining Company, 212 Pioneer Building, Lake Charles, Louisiana.

C. D. GIGIAMBATTISTA is in the employ of the Standard Oil Company of Texas at Midland, Texas.

ROY F. BEERY, JR., formerly with the Shell Oil Company, Inc., is superintendent for the Danciger Oil and Refining Company at Norman, Oklahoma.

E. C. DILLON has left the Gulf Oil Corporation. He is associated with the American Equity Oil and Gas Company, Commerce Building, Houston, Texas.

ROBERT O. BRACE is in the employ of the Standard Oil Company of California, Los Angeles.

G. F. THORNHILL has left the Northwestern Company, and is now with the Baroid Sales Division at Casper, Wyoming.

LESLIE BOWLING is no longer connected with the Hunt Oil Company. He is in business for himself as consulting geologist, 529 Whitney Bank Building, New Orleans, Louisiana.

EDWIN H. HUNT died by drowning near Calgary, Alberta, Canada, July 10. He was in the employ of the McColl-Frontenac Oil Company, Ltd.

H. Baggelaar has left Egypt to take up the post of paleontologist with the N. V. Bataafsche Petroleum Maatschappij, Balikpapan, Borneo, Indonesia.

ROBERT R. WHEELER is chief geologist for C. P. Burton, Oil, 911 Continental Building, Dallas, Texas.

JOHN W. OLSON, geologist, has been transferred from the Chanslor-Canfield Midway Oil Company, Bakersfield, California, to the Oil Development Company of Texas, 900 Polk Street, Amarillo, Texas.

H. CLAIRE MATHENY has left the Tex Harvey Oil Company to work for the Danciger Oil and Refining Company, Fort Worth, Texas.

ROBERT B. GAINES, JR., is a teaching fellow at the University of Texas while working on his Master's degree in geology.

P. A. WALLACE, formerly chief geologist for the Stephens Petroleum Company, is a consultant in the Tradesmen's National Bank Building, Oklahoma City, Oklahoma.

E. E. REHN, recently division geologist of the western division of the Sohio Petroleum Company at Oklahoma City, is returning to Evansville, Indiana, to operate as an independent in the Tri-State area. Prior to transferring to Oklahoma City, on April 1, Rehn was eastern division geologist for the Sohio at Evansville. He has been in charge of exploration work for the Sohio in Illinois and Indiana 7 years.

ROY E. DARKE, geologist with the Standard Oil Company of California for 30 years, has retired.

CHARLES EDWIN MOHLER is chief geologist for the National Associated Petroleum Company, Tulsa, Oklahoma. He succeeds B. A. LILIENBORG, deceased.

RUSSELL C. CUTLER, of Golden, Colorado, has gone to Caracas, Venezuela, for the Socony-Vacuum Oil Company.

ROBERT L. PAINTER has left the Pure Oil Company to accept employment with the Barnsdall Oil Company, Tulsa, Oklahoma.

L. G. KEPPLER has resigned from the Lewis Oil Company and has opened a consulting office at 826 Alamo Bank Building, San Antonio, Texas.

The Geological Forum of the Pacific Section of the A.A.P.G. presented two speakers at its meeting in Los Angeles, California, August 15: PAUL D. KRYNINE, Pennsylvania State College, "Origin of Redbeds," and F. D. BODE, The Texas Company, Los Angeles, "Observations on the Geology of Ethiopia."

C. LOUIS CHASE has resigned from The Texas Company. He is now employed as geologist for Ralph Lowe, Midland, Texas.

CLARENCE W. HUGHES is in the employ of the Carter Oil Company at Denver, Colorado.

FRANK C. CRAWFORD has completed graduate work at the Louisiana State University for the Master of Science degree in geology and has accepted a position as geologist with the Ohio Oil Company at Shreveport, Louisiana.

CARLTON J. LEITH has left Indiana University. His address is Corps of Engineers, Materials Testing Laboratory, Sausalito, California.

LAURENCE F. LEES and E. RUSSELL LLOYD, JR., are associated with the consulting firm of JOHN M. HILLS, E. RUSSELL LLOYD, and WILLIAM Y. PENN, Suite 21, Permian Building, Midland, Texas.

CHARLES N. GOULD, honorary member of the Association, died at Norman, Oklahoma, August 13, at the age of 81 years. He had been closely associated with the department of geology at the University of Oklahoma and the State Geological Survey from their beginnings.

DWIGHT H. FORTINE, chief geologist of the California division of the Barnsdall Oil Company at Glendale, California, died on August 3, at the age of 44 years.

WILLIAM E. HUMPHREY, of the Phillips Petroleum Company, has been transferred from Bogota, Colombia, to Caracas, Venezuela. His address is Apartado Aereo 1031.

CHARLES G. HAVARD has completed the requirements for the degree of Master of Arts at the University of Texas and is continuing his graduate studies at Cornell University, Ithaca, New York, where he is a graduate assistant in the department of geology.

MISSISSIPPI GEOLOGICAL SOCIETY FIELD TRIP

AUGUST 24–27, 1949

The 7th Field Trip of the Mississippi Geological Society was conducted through the pre-Cambrian and Paleozoic sediments of northern Alabama and southwest-central Tennessee. The attendance was 85. Thirty-four outcrops were visited. Field leaders included DAVID C. HARRELL and HUGH D. PALLISTER on the pre-Cambrian; ARTHUR BLAIR and ROBERT MORTON on the folded Appalachians in the Birmingham area; WALTER B. JONES, WINNIE MCGLAMERY, and ROBERT PAVLOVIC in the Warrior Basin area; and JOHN R. BALL and JAMES L. MARTIN on the area of the western valley of the Tennessee River.

Oral papers presented at the dinner meeting in Birmingham, on August 24, included "Economic Geology of the Birmingham District," by ARTHUR BLAIR; "Recent Studies of the Chattanooga Shale," by LOUIS C. CONANT; and "Paleozoic Rocks in Mississippi," by WILLIAM C. MORSE.

The guidebook contains an introductory paper by FREDERIC F. MELLEN, a paper on the "Crystalline Area of Alabama" by DAVID C. HARRELL, and one on "Foraminifers in the Black Warrior Basin of Mississippi and Alabama" by M. L. THOMPSON and FREDERIC F. MELLEN. The road log describes all stops made on the trip and contains numerous profiles, cross sections, areal geologic maps, stratigraphic columns, and photographs. Copies of the guidebook may be obtained, at $4.25 a copy prepaid, by writing W. H. KNIGHT, treasurer, Box 2253, West Jackson, Mississippi. Students may obtain copies, through their professors, at $2.25 a copy, prepaid.

A Paleozoic cross section through northwestern Alabama and northeastern Mississippi is available at $2.25 a copy, prepaid.

IRVIN J. ANDERSON resigned his position as assistant professor of geology at the University of Texas. He is in the geological department of the Stanolind Oil and Gas Company, Lake Charles, Louisiana.

E. PAUL KNEEDLER, formerly with the Atlantic Refining Company at Shreveport, Louisiana, is district geologist with the Midstates Oil Corporation, Jackson, Mississippi.

R. C. MCFADDEN, JR., is employed as a petroleum engineer and geologist with the Southern California Edison Company in Los Angeles, California. He was previously with the Union Oil Company of California at Midland, Texas.

New officers of the Appalachian Geological Society, Charleston, West Virginia, are: president, W. B. MAXWELL, United Fuel Gas Company; vice-president, JOHN GALPIN, 1901 Kanawha Valley Building; associate vice-president, H. P. MCJUNKIN, McJunkin Supply Company; secretary-treasurer, W. T. ZIEBOLD, Spartan Gas Company; editor, F. SIEGEL WORKMAN, JR., Acme Engineering Services.

J. ELMER THOMAS, one of the founders and the first president of the American Association of Petroleum Geologists (Southwestern Association of Petroleum Geologists in 1917) died in Fort Worth, Texas, August 20. Death was caused by a heart attack. He was 57 years of age.

DONALD K. MACKAY, chief geologist, Arkansas Oil and Gas Commission, is spending the latter half of September in New York City.

The American Association for the Advancement of Science will hold its 116th meeting in New York, December 26–31. Advance registration blanks may be obtained by writing to American Association for the Advancement of Science, 1515 Massachusetts Avenue

N. W., Washington 5, D. C. The A.A.A.S. would welcome membership applications from A.A.P.G. members.

The Wyoming Geological Association, DONALD E. EDSTROM, chairman of the correlation committee, announces publication of its "Electric Log Correlation Chart of the Wind River Basin and Adjacent Areas of Wyoming," showing the commonly accepted correlation of the strata from the lower Upper Cretaceous to the pre-Cambrian. The chart is in two sheets, 40×72 inches, and 24×40 inches. The price is $3.00, folded, set of two sheets, or $3.25, rolled and mailed in tube. Copies are available from Petroleum Information, Box 2452, Casper, Wyoming.

The Indiana-Kentucky Geological Society has elected the following officers for 1949–1950: president, H. W. BODKIN, Superior Oil Company, Evansville, Indiana; vice-president D. G. SUTTON, Sun Oil Company, Evansville, Indiana; secretary-treasurer, J. B. VAUGHAN, Ashland Oil and Refining Company, Henderson, Kentucky.

The Tulsa Geological Society announces publication of its 17th annual *Digest*, edited by JOHN C. MAHER of the United States Geological Survey and managed by V. L. FROST of the Ohio Oil Company. This volume of 196 pages and 32 illustrations contains 23 digests of papers on foreign and United States regional and local geology, geophysics, photogeology, and exploration policies. Papers on the Velma, Ceres, Sholem Alechem, and Northwest Sulphur pools of Oklahoma, the Lawson-Chapman area of Texas, and the Anadarko basin of Oklahoma and Kansas are included. A directory of members listed both by name and company affiliation is appended to the text. Non-members of the Tulsa Society may obtain copies at $1.00 each from V. L. FROST, Ohio Oil Company, Thompson Building, Tulsa, Oklahoma.

H. B. FUQUA has resigned his position as assistant to the vice-president of producing operations of the Gulf Oil Corporation, Houston division. He is succeeded by B. G. MARTIN, who has been division geologist at Fort Worth, Texas, Fuqua joined the Gulf in 1922. He was A.A.P.G. president in 1937.

DAN EDWARDS FERAY has left the Bureau of Economic Geology, University of Texas, Austin, Texas. Effective September 1, his address is Geology Department, University of Tulsa, Tulsa, Oklahoma.

W. KENLEY CLARK has recently been transferred from the Shreveport Division of The Superior Oil Company to the Houston office as chief geologist.

C. E. B. CONYBEARE, recently at the State College of Washington, Pullman, Washington, has been appointed assistant professor of geology at the University of Manitoba, Winnipeg, to teach petrology.

L. L. MCCORMICK, JR., recently in the geology department at Louisiana State University, is with The California Company, at New Orleans, Louisiana.

HENRY HERMAN KRUSEKOPF, JR., is with the Magnolia Petroleum Company at Roswell, New Mexico

JOHN ELIOT ALLEN, recently at Pennsylvania State College, is now in the department of geology at the New Mexico School of Mines, Socorro, New Mexico.

W. K. ESGEN has resigned from the Standard Oil Company (New Jersey). His address is 1706 Esperson Building, Houston, Texas.

D. KEITH LUPTON is at Dartmouth College, Hanover, New Hampshire, in care of the geology department.

PROFESSIONAL DIRECTORY

CALIFORNIA

CANADA

GEOLOGICAL AND GEOPHYSICAL SOCIETIES

THE SOCIETY OF EXPLORATION GEOPHYSICISTS

President - - - - - - Andrew J. Gilmour
Amerada Petroleum Corporation
Box 2040, Tulsa, Oklahoma

Vice-President - - - - - George E. Wagoner
Carter Oil Company
Shreveport, Louisiana

Editor - - - - - - - - - - R. A. Geyer
Humble Oil and Refining Company
Houston, Texas

Secretary-Treasurer - - - - - - K. E. Burg
Geophysical Service, Inc.
6000 Lemmon Ave., Dallas, Texas

Past-President - - - - - - L. L. Nettleton
Gravity Meter Exploration Co.
1348 Esperson Bldg., Houston, Tex.

Business Manager - - - - - Colin C. Campbell
Room 210, 817 South Boulder, Tulsa, Oklahoma
P.O. Box 1614

CALIFORNIA

PACIFIC SECTION AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

President - - - - - - - - Clifton W. Johnson
Richfield Oil Corporation
Room 430, Richfield Bldg.
Los Angeles 13, California

Vice-President - - - - - - John E. Kilkenny
Chanslor-Canfield Midway Oil Company
4549 Produce Plaza West, Los Angeles 11

Secretary-Treasurer - - - - - Harold E. Rader
Standard Oil Company, Box 2437, Terminal Annex
Los Angeles 54

Monthly meetings. Visiting geologists are welcome.

CALIFORNIA

SAN JOAQUIN GEOLOGICAL SOCIETY
BAKERSFIELD, CALIFORNIA

President - - - - - - Robert B. Hutcheson
The Superior Oil Company, Box 1031

Vice-President - - - - - Floyd L. Johnson
Honolulu Oil Corporation

Secretary-Treasurer - - - Maxwell G. Caben
Seaboard Oil Company of Delaware, Box 7

Dinner meetings on 2d Tuesday of each month or as announced, El Tejon Hotel, Bakersfield.

COLORADO

ROCKY MOUNTAIN ASSOCIATION OF GEOLOGISTS
DENVER, COLORADO

President - - - - - - - - - Dart Wantland
U. S. Reclamation Service

1st Vice-President - - - - - S. W. Lohman
U. S. Geological Survey
136 New Customhouse

2d Vice-President - - - - - - E. W. Scudder
J. M. Huber Corporation
Box 2098

Secretary-Treasurer - - - - - Kenneth L. Gow
Superior Oil Company of California
506 First National Bank Building

Evening dinner (6:30) and technical program (8:00) first Tuesday each month or by announcement.

FLORIDA

SOUTHEASTERN GEOLOGICAL SOCIETY
Box 841
TALLAHASSEE, FLORIDA

President - - - - - - - - W. C. Blackburn
Humble Oil and Refining Company, Box 506

Secretary-Treasurer - - - - - Albert A. Raasch
Humble Oil and Refining Company,
Box 506

Meetings will be announced. Visiting geologists and friends are welcome.

ILLINOIS

ILLINOIS GEOLOGICAL SOCIETY

President - - - - - - - - - - - C. E. Brehm
C. E. Brehm Drilling & Producing
Mt. Vernon

Vice-President - - - - - - - - Joseph Neely
Magnolia Petroleum Company
Box 535, Mt. Vernon

Secretary-Treasurer - - - - - Lloyd A. Harris
Carter Oil Company, Box 568, Mattoon

Meetings will be announced.

INDIANA-KENTUCKY

INDIANA-KENTUCKY GEOLOGICAL SOCIETY
EVANSVILLE, INDIANA

President - - - - - - - - H. W. Bodkin
Superior Oil Company

Vice-President - - - - - - - D. G. Sutton
Sun Oil Company, Box 717

Secretary-Treasurer - - - - - J. B. Vaughan
Ashland Oil and Refining Company
Henderson, Kentucky

Meetings will be announced

KANSAS

KANSAS GEOLOGICAL SOCIETY
WICHITA, KANSAS

President - - - - - - - - - Don W. Payne
Sinclair Prairie Oil Company

Vice-President - - - - - - - T. G. Wright
Stanolind Oil and Gas Company

Secretary-Treasurer - - - - Victor F. Reiserer
Superior Oil Company, 510 K.F.H. Bldg.

Regular Meetings: 7:30 P.M., Geological Room, University of Wichita, first Tuesday of each month. Noon luncheons, first and third Monday of each month at Wolf's Cafeteria. The Society sponsors the Kansas Well Log Bureau, and the Kansas Well Sample Bureau, 508 East Murdock. Visiting geologists and friends welcome.

OKLAHOMA

SHAWNEE GEOLOGICAL SOCIETY
SHAWNEE, OKLAHOMA

President - - - - - - - - - Doyle M. Burke
The Texas Company, Box 1007

Vice-President - - - - - - - Jack W. Davies
Halliburton Oil Well Cementing Company

Secretary-Treasurer - - - - - Marcelle Mousley
Atlantic Refining Company, Box 169

Meets the third Thursday of each month at 8:00 P.M., at the Aldridge Hotel. Visiting geologists welcome.

TULSA GEOLOGICAL SOCIETY
TULSA, OKLAHOMA

President - - - - - - - - - - - L. H. Lukert
The Texas Company, Box 2420
1st Vice-President - - - - - Daniel A. Busch
Carter Oil Company, Box 801
2d Vice-President - - - - John M. Nash
Shell Oil Company, Box 1191
Secretary-Treasurer - - - - Mary Whitehead
Stanolind Oil and Gas Company, Box 591
Editor - - - - - - - - Oscar E. Wagner, Jr.
Mid-Continent Petroleum Corporation, Box 381
Business Manager, Digest - - - - V. L. Frost
Ohio Oil Company, Thompson Building

Meetings: First and third Mondays, each month, from October to May, inclusive, at 8:00 P.M., University of Tulsa, Lorton Hall. Luncheons: Every Friday (October-May), Chamber of Commerce Building.

PENNSYLVANIA

PITTSBURGH GEOLOGICAL SOCIETY
PITTSBURGH, PENNSYLVANIA

President - - - - - - - - Charles F. Bassett
Gulf Oil Corporation, Box 1166
Vice-President - - - - - - - - R. E. Sherrill
University of Pittsburgh
Secretary - - - - - - - - - - C. E. Prouty
University of Pittsburgh
Treasurer - - - - - - - - - Sidney S. Galpin
Peoples Natural Gas Company
545 William Penn Place

Meetings held each month, except during the summer. All meetings and other activities by special announcement.

TEXAS

ABILENE GEOLOGICAL SOCIETY
ABILENE, TEXAS

President - - - - - - - - - - - - J. R. Day
Pan American Production Company

Vice-President - - - - - David M. Grubbs
Drilling and Exploration Company

Secretary-Treasurer - - - - - C. S. Noland
Skelly Oil Company

Meetings: 2d Thursday of each month, 7:30 P.M., Wooten Hotel.

TEXAS

CORPUS CHRISTI GEOLOGICAL SOCIETY
CORPUS CHRISTI, TEXAS

President - - - - - - - - - James D. Burke
Seaboard Oil Company of Delaware, Box 601

Vice-President - - - - - W. H. Wallace, Jr.
La Gloria Corporation, Driscoll Building

Secretary-Treasurer - - - - H. W. Volk, Jr.
Tide Water Associated Oil Company
Driscoll Building

Regular luncheons, every Thursday, Terrace Annex Room, Robert Driscoll Hotel, 12:00. Special night meetings by announcement.

DALLAS GEOLOGICAL SOCIETY
DALLAS, TEXAS

President - - - - - - - - - John T. Rouse
Magnolia Petroleum Company
P.O. Box 900

Vice-President - - - - - - - - H. V. Tygrett
The Atlantic Refining Company
P.O. Box 2819

Secretary-Treasurer - - - - Gilbert P. Moore
Consulting, 501 Continental Building

Executive Committee - - - - - Edgar Kraus
Atlantic Refining Company
Box 2819

Meetings: Monthly luncheons and night meetings by announcement.

EAST TEXAS GEOLOGICAL SOCIETY
TYLER, TEXAS

President - - - - - - - - - - - G. C. Clark
Stanolind Oil and Gas Company
Box 660

Vice-President - - - - - R. M. Trowbridge
Consultant, 225 Owen Building

Secretary-Treasurer - - - - - Rosella L. Bunch
Shell Oil Company, Inc., Box 2037

Luncheons: Each week, Monday noon, Blackstone Hotel.
Evening meetings and programs will be announced. Visiting geologists and friends are welcome.

FORT WORTH GEOLOGICAL SOCIETY
FORT WORTH, TEXAS

President - - - - - - - - - F. H. Schouten
Stanolind Oil and Gas Company
Box 1410

Vice-President - - - - - - H. C. Vanderpool
Texas Pacific Coal and Oil Company
Box 2110

Secretary-Treasurer - - - - - Thomas Nichols
Rowan Oil Company
Commercial Standard Building

Meetings: Luncheon at noon, Hotel Texas, first and third Mondays of each month. Visiting geologists and friends are invited and welcome at all meetings.

TEXAS

HOUSTON GEOLOGICAL SOCIETY
HOUSTON, TEXAS

President - - - - - - - - Hershal C. Ferguson
Consultant, 935 Mellie Esperson Building

Vice-President - - - - - - - - - R. R. Rieke
Schlumberger Well Surveying Corporation

Secretary - - - - - - - - - James H. McGuirt
Tide Water Associated Oil Company

Treasurer - - - - - - - - - - - Marjorie Fuqua
Humble Oil and Refining Company

Regular meeting held the second and fourth Mondays at noon (12 o'clock), Mezzanine floor, Texas State Hotel. For any particulars pertaining to the meetings write or call the secretary.

PANHANDLE GEOLOGICAL SOCIETY
AMARILLO, TEXAS

President - - - - - - - - - G. E. Hatton
Phillips Petroleum Company, Box 1761

Vice-President - - - - - - Robert F. Herron
Oil Development Company, 900 Polk St.

Secretary-Treasurer - - - - - Robert B. Totten
Sun Oil Company, Box 46

Meetings: Luncheon 1st and 3d Wednesdays of each month, 12:00 noon, Herring Hotel. Special night meetings by announcement.

NORTH TEXAS GEOLOGICAL SOCIETY
WICHITA FALLS, TEXAS

President - - - - - - - Joseph W. McDonald
Shell Oil Company, Inc., Box 2010

Vice-President - - - - - Ralph H. McKinlay
Panhandle Producing and Refining Company
Box 1191

Secretary-Treasurer - - - - Walter L. Ammon
Stanolind Oil and Gas Company
Box 1680

Meetings: Luncheon 1st and 3d Thursdays of each month, 12:00 noon, Texas Room, Holt Hotel. Evening meetings by special announcement. Visiting geologists and friends are cordially invited to all meetings.

SOUTH TEXAS GEOLOGICAL SOCIETY
SAN ANTONIO, TEXAS

President - - - - - - - - - Paul B. Hinyard
Shell Oil Company
2000 Alamo National Building

Vice-President - - - - - - - - J. Boyd Best
Ohio Oil Company

Secretary-Treasurer - - - Louis H. Haring, Jr.
Stanolind Oil and Gas Company

Meetings: One regular meeting each month in San Antonio. Luncheon every Monday noon at Milam Cafeteria, San Antonio.

TEXAS

WEST TEXAS GEOLOGICAL SOCIETY
MIDLAND, TEXAS
Box 1595

President - - - - - - - - - W. T. Schneider
Honolulu Oil Corporation, Box 1391

Vice-President - - - - - Ralph D. Chambers
Continental Oil Company, Box 431

Secretary - - - - - - - - - Jesse A. Rogers
The Texas Company, Box 1270

Treasurer - - - - - - John V. Norman, Jr.
Forest Oil Corporation, Box 1821

Meetings will be announced.

UTAH

UTAH GEOLOGICAL SOCIETY
SALT LAKE CITY, UTAH
P.O. Box 1015

President - - - - - - - - J. Stewart Williams
Utah State Agricultural College, Logan

Vice-President - - - - - - A. Lee Christensen
Utah Construction Company, Salt Lake City

Corresponding Secretary - - - - Reed F. Welch
American Smelting and Refining Co., Salt Lake City

Recording Secretary - - - - - - Max Erickson
University of Utah, Salt Lake City

Treasurer - - - - - - - - F. W. Christiansen
University of Utah, Salt Lake City

Sponsors an annual field trip for which a guidebook is published.
Meetings by announcement.

WEST VIRGINIA

APPALACHIAN GEOLOGICAL SOCIETY
CHARLESTON, WEST VIRGINIA
P.O. Box 2605

President - - - - - - - - - W. B. Maxwell
United Fuel Gas Company, Box 1273

Vice-President - - - - - - - - John Galpin
1901 Kanawha Valley Building

Associate Vice-President - - - H. P. McJunkin
McJunkin Supply Company

Secretary-Treasurer - - - - W. T. Ziebold
Spartan Gas Company, Box 766

Editor - - - - - - - F. Seigal Workman, Jr.
Acme Engineering Services, Box 923

Meetings: Second Monday, each month, except June, July and August, at 6:30 P.M., Daniel Boone Hotel.

WYOMING

WYOMING GEOLOGICAL ASSOCIATION
CASPER, WYOMING
P.O. Box 545

President - - - - - - - - - Jed B. Maebius
Gulf Oil Corporation, Box 1971

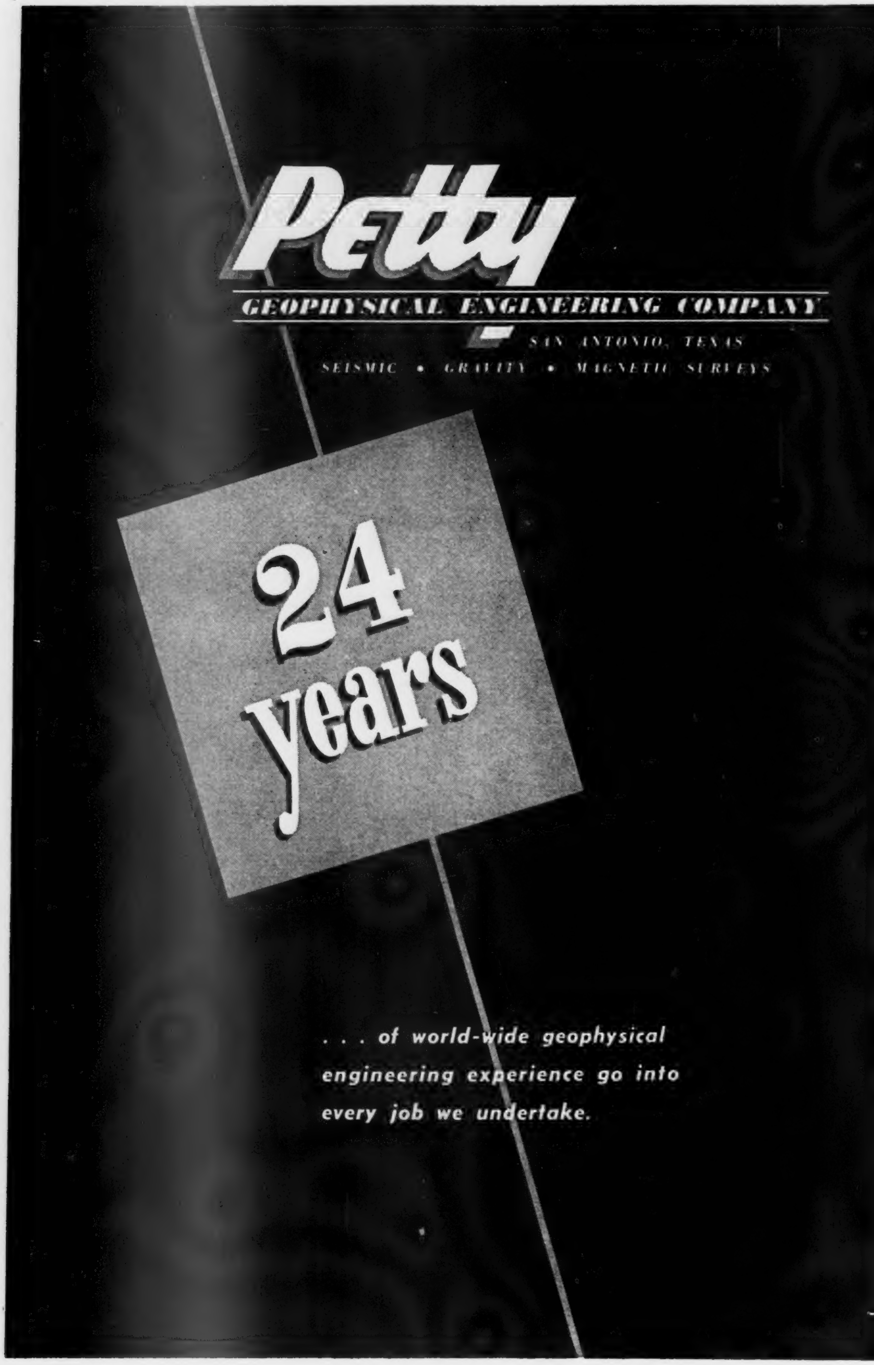
1st Vice-President - - - - Emmett E. Schieck
Morton Oil Company, Box 1970

2d Vice-President (Programs) - Donald E. Edstrom
British-American Oil Producing Company, Box 620

Secretary - - - - - - - J. B. Headley, Jr.
Atlantic Refining Company

Treasurer - - - - - - - - - George L. Goodin
Petroleum Information, Inc.

Informal luncheon meetings every Friday, 12 noon, Townsend Hotel. Visiting geologists welcome. Special meetings by announcement.


Petty
GEOPHYSICAL ENGINEERING COMPANY
SAN ANTONIO, TEXAS
SEISMIC • GRAVITY • MAGNETIC SURVEYS
24 years
. . . of world-wide geophysical engineering experience go into every job we undertake.

The best place to find oil is

WHERE NOBODY HAS LOOKED BEFORE

in the proven trends throughout the oil-bearing sections of the world.

In the search for oil in rough country, seismograph crews in the past have been restricted to shooting near road patterns . . . or only as far off the road as trucks could penetrate the rough country. As a result, only road areas have been proven. Now, unsurveyed regions in proven areas offer the best prospects for new oil reserves.

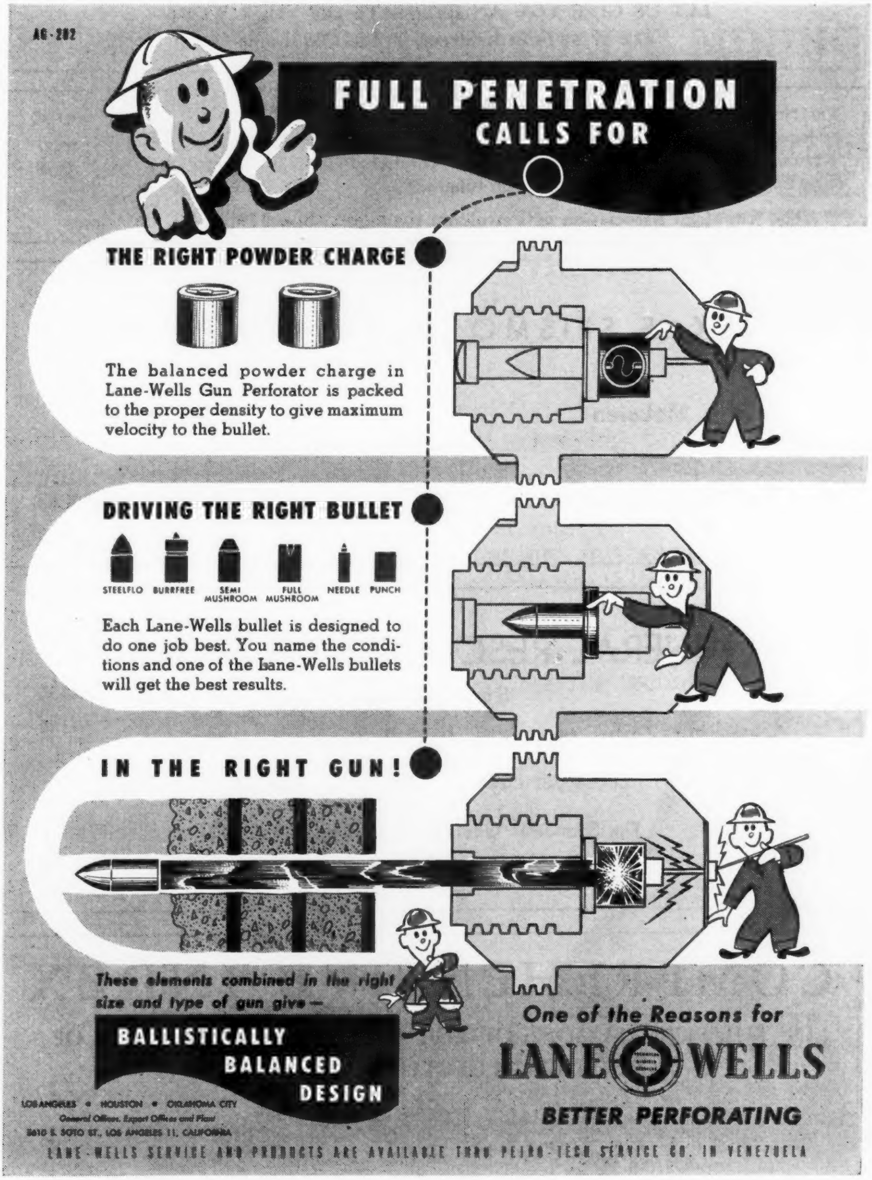
By adapting proved portable marine instruments to land operations, Marine Exploration is now able to shoot dip and strike lines oriented to local geology regardless of the pattern of road systems at a cost comparable to conventional seismograph surveys. That's how Marine Exploration can help you look for new oil reserves in unsurveyed sections of mountainous or swamp country . . . where nobody has looked before.

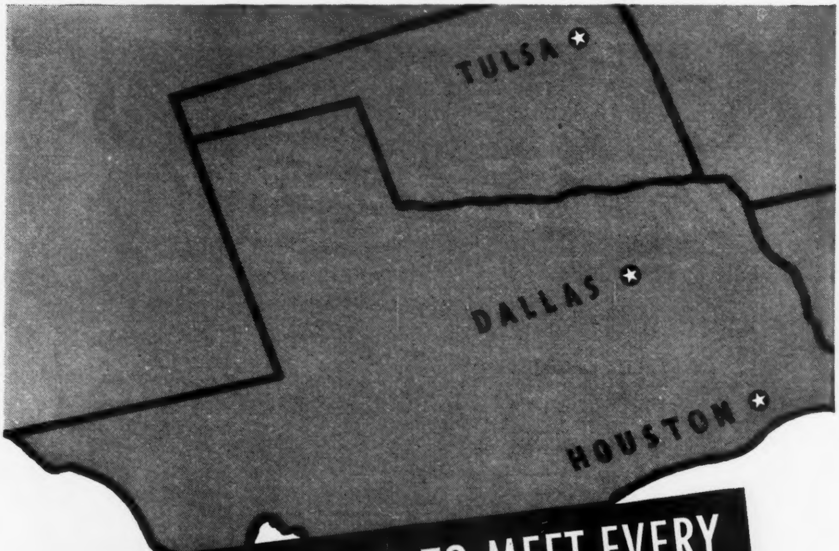
We will appreciate your inquiries about the availability of Marine Exploration Crews for your new exploration programs.

MARINE EXPLORATION CO.

3732 WESTHEIMER ROAD, HOUSTON 6, TEXAS
423 BALTER BUILDING, NEW ORLEANS, LA.

FOREIGN AGENT: Jorge Besquin de V, Reforma Num. 1-656, Mexico D.F.


AG-202
FULL PENETRATION
CALLS FOR
THE RIGHT POWDER CHARGE
The balanced powder charge in Lane-Wells Gun Perforator is packed to the proper density to give maximum velocity to the bullet.
DRIVING THE RIGHT BULLET
STEELFLO
BURRFREE
SEMI MUSHROOM
FULL MUSHROOM
NEEDLE
PUNCH
Each Lane-Wells bullet is designed to do one job best. You name the conditions and one of the Lane-Wells bullets will get the best results.
IN THE RIGHT GUN!
These elements combined in the right size and type of gun give—
BALLISTICALLY BALANCED DESIGN
One of the Reasons for
LANE WELLS
BETTER PERFORATING
LOS ANGELES • HOUSTON • OKLAHOMA CITY
General Offices, Export Offices and Plant
5610 S. SOTO ST., LOS ANGELES 11, CALIFORNIA
LANE-WELLS SERVICE AND PRODUCTS ARE AVAILABLE THRU PETRO-TECH SERVICE CO. IN VENEZUELA



3 LOCATIONS TO MEET EVERY GEOPHYSICAL SUPPLY NEED
WHEN YOU NEED IT!

Within overnight shipping distance of the majority of exploration activity, Harrison's three supply points provide service when you need it for both geophysical field crews and laboratories. Orders are shipped from the Harrison store nearest your location to give you maximum benefit of savings in freight rates. When you need geophysical supplies . . . for laboratory or field crews . . . call Harrison **first!** Our three locations are completely stocked to meet your needs **when you need it.**

A complete line of geophysical and electronic supplies

Harrison
Equipment Co., Inc.

MAIN OFFICES: 1422 SAN JACINTO, HOUSTON
BRANCHES: 6234 PEELER ST., DALLAS • 1124 E. 4TH ST., TULSA


NEW SURVEYING
MICRO Altimeter
Graduations:
ONE FOOT
Range:
6,000 FEET
MODEL M1
Another FIRST by the makers of the established world standard in accuracy and dependability . . . the new Surveying MICRO Altimeter for all field and mine ventilation surveys . . . Constructed for lifetime service of finest materials to highest standards . . . exclusive friction-free, zero-gauging principle. Equipped with rugged leather carrying case, magnifier, thermometer and operational procedures.
Model M 1 illustrated . . . other models available . . . see your dealer or write direct.
SURVEYING MICRO ALTIMETER
AMERICAN PAULIN SYSTEM
1847 S. Flower Street, Los Angeles 15, California

Cores

FOR CABLE TOOL OPERATORS that are accurate uncontaminated samples of the formation...

BAKER CABLE TOOL CORE BARREL

Product No. 520

PRESENT POSITIVE PROOF
to eliminate danger of passing up productive sands; for selecting proper casing locations; for determining oil-bearing sands; for studying the porosity, permeability, or other characteristics of the formation.

EASY AND FAST TO RUN
Any experienced cable tool driller can take good cores right from the start, and coring is as fast as straight drilling. Accurate, uncontaminated cores can be taken from a wide range of formations.

LOW-COST OPERATION
Minimum operating expense and low upkeep cost assure low-cost coring, and justify taking as many cores as desired. The sturdy construction of the Baker Cable Tool Core Barrel insures long life—the few wearing parts are inexpensive and easily replaced.

Complete information is in the BAKER (or Composite) CATALOG—or contact any Baker representative or office.

BAKER OIL TOOLS, INC.
HOUSTON • LOS ANGELES • NEW YORK

NEW! The JOY #150 MOTORIZED DRILL RIG

Latest in Design First in Performance

JOY'S new #150 Motorized Drill Rig is designed for heavy-duty seismograph, electrical logging, structure testing and shallow water well drilling down to 1500 feet. It incorporates the most modern improvements in drill rig design—has proved itself outstanding in the field within its capacity range. Note these exclusive features:

- ★ **All chains are oil-bath lubricated and run in oil-tight cases.**
- ★ **Equipped with conventional oil-bath rotary table with 6⅜" opening. For running larger casing, the rotary table is retractable 14 inches.**
- ★ **Mast elevating and lowering cylinders are arranged to eliminate over-travel on either the up or down stroke.**
- ★ **Main drum clutch and sand-reel clutch use same friction plates.**

WRITE FOR BULLETIN

The efficient and highly portable #150 Motorized Drill Rig on the job.

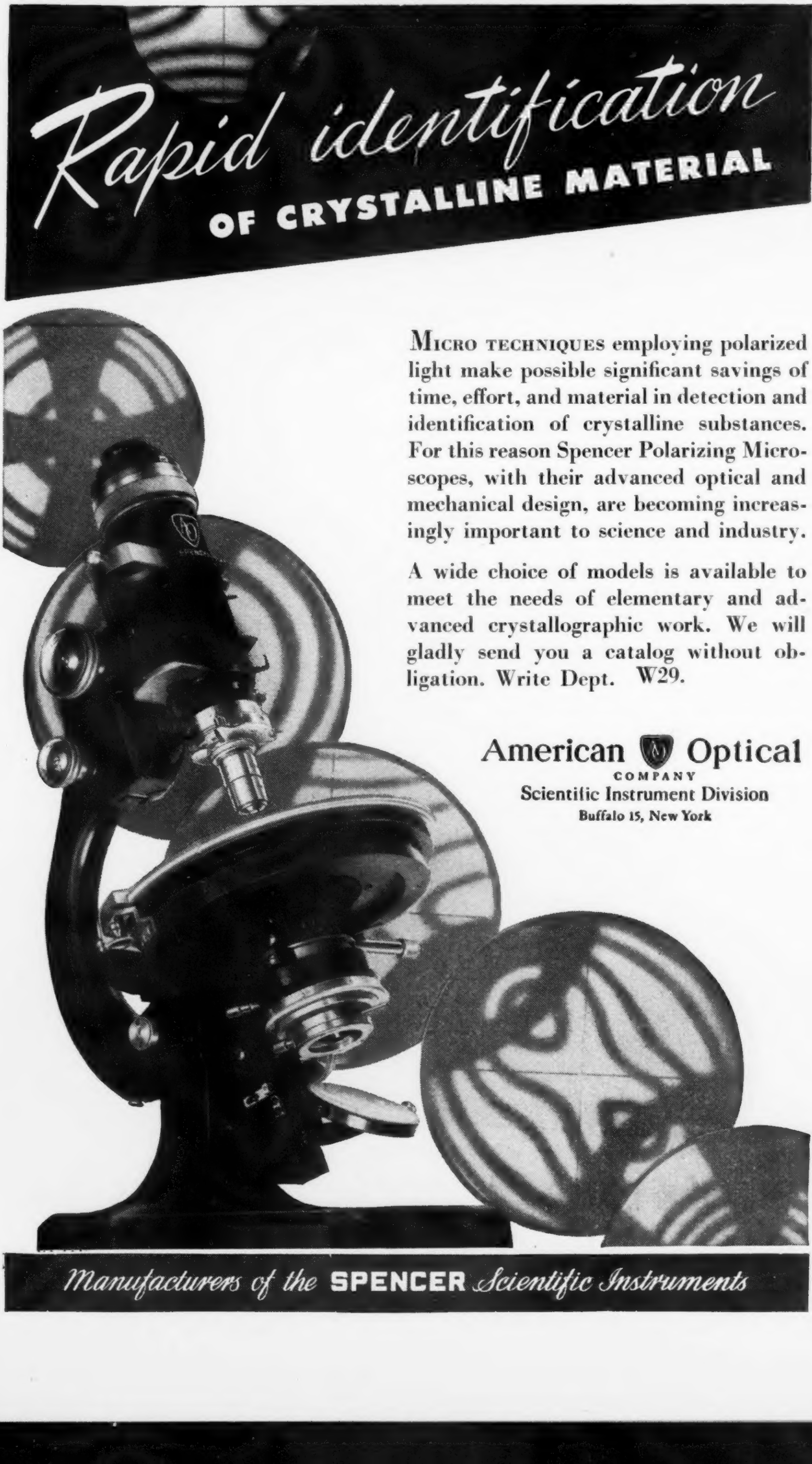
Consult a Joy Engineer

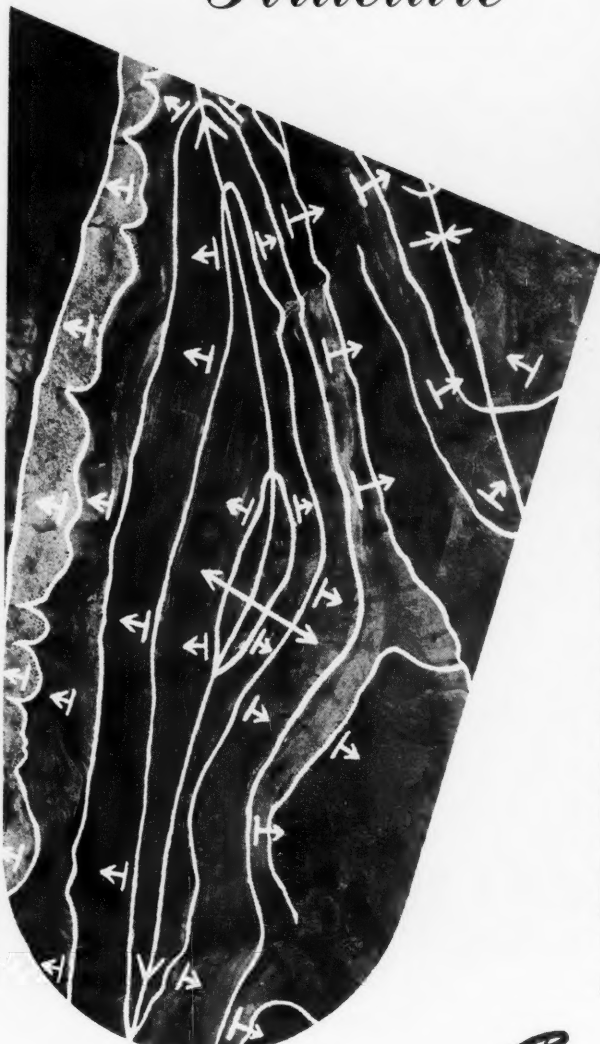
W&D 02195

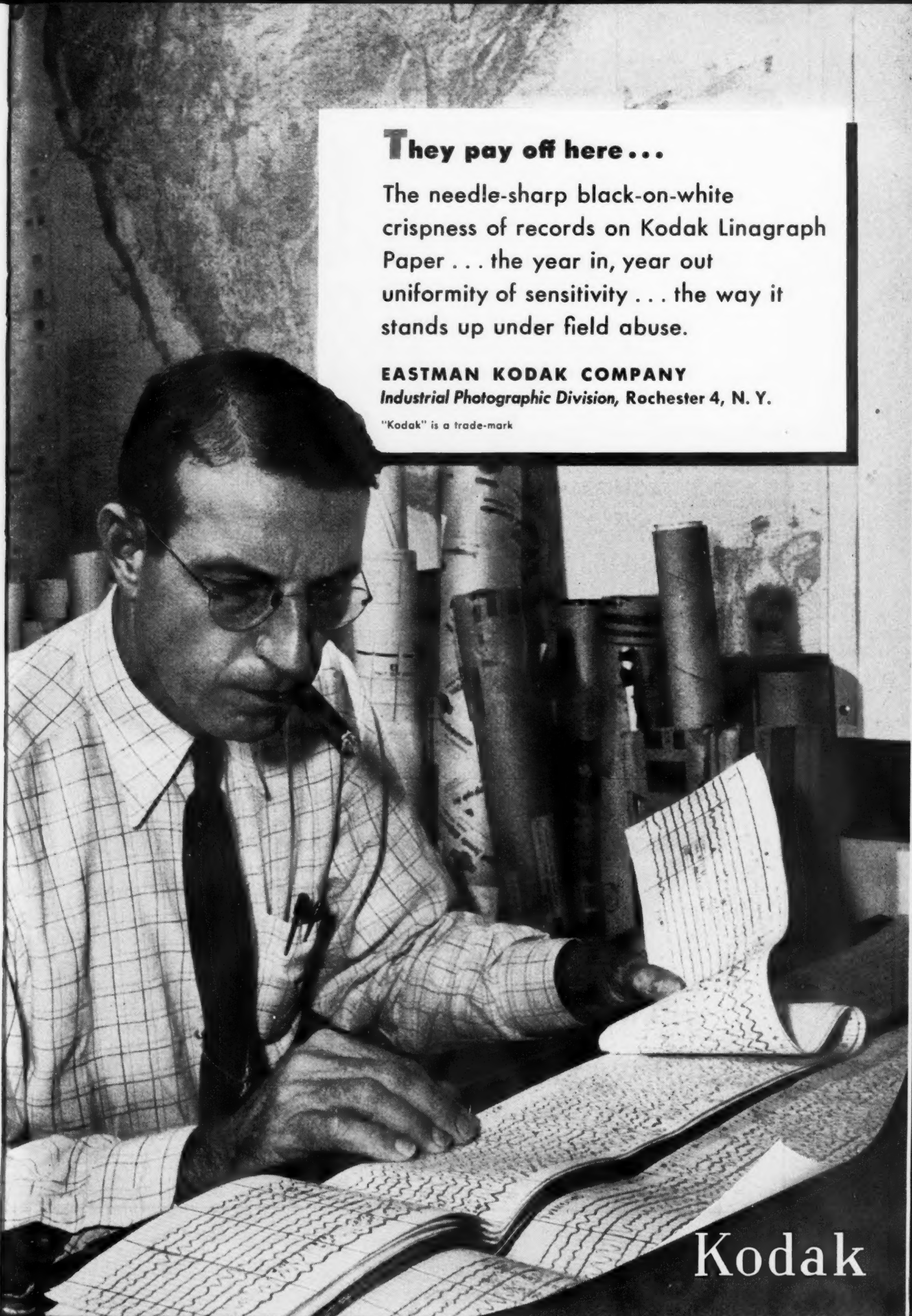
JOY MANUFACTURING COMPANY

GENERAL OFFICES: HENRY W. OLIVER BUILDING · PITTSBURGH 22, PA.

IN CANADA: JOY MANUFACTURING COMPANY (CANADA) LIMITED, GALT, ONTARIO


Rapid identification
OF CRYSTALLINE MATERIAL
MICRO TECHNIQUES employing polarized light make possible significant savings of time, effort, and material in detection and identification of crystalline substances. For this reason Spencer Polarizing Microscopes, with their advanced optical and mechanical design, are becoming increasingly important to science and industry.
A wide choice of models is available to meet the needs of elementary and advanced crystallographic work. We will gladly send you a catalog without obligation. Write Dept. W29.
American Optical
COMPANY
Scientific Instrument Division
Buffalo 15, New York
Manufacturers of the SPENCER Scientific Instruments




They pay off here . . .
The needle-sharp black-on-white crispness of records on Kodak Linagraph Paper . . . the year in, year out uniformity of sensitivity . . . the way it stands up under field abuse.
EASTMAN KODAK COMPANY
Industrial Photographic Division, Rochester 4, N. Y.
"Kodak" is a trade-mark
Kodak

PRICE LIST OF THE BULLETIN

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

Box 979, Tulsa 1, Oklahoma, U.S.A.

The monthly *Bulletin* contains authoritative major articles on petroleum geology and allied subjects, and minor notes, discussions, and reviews. Annual subscription, $15.00 (outside United States, $15.40). Contents of Vols. I–XXIX (1917–1945) are indexed in detail in the *Comprehensive Index* (price to members, $3.00; to others, $4.00) of all A.A.P.G. publications (1917–1945); these volumes and the index may be consulted at Association headquarters and in many college and public libraries. Volumes and numbers remaining for sale are listed here. Educational institutions are invited to write for special prices

BULLETINS AVAILABLE (1921–1945). See COMPREHENSIVE INDEX FOR CONTENTS ALSO, ANNUAL CONTENTS INDEXED IN EACH DECEMBER NUMBER

Any single number....................(To members, $1.00) $1.50
Special: Vols. XIII–XV, clothbound, per Vol....................(To members, $5.00) $6.00
Vols. XIII–XV, 12 paper-covered monthly numbers in each Vol., per Vol....................(To members, $5.00) $6.00

Year	*Vol.*	*No.*	*Year*	*Vol.*	*No.*	*Year*	*Vol.*	*No.*
1921	V	3–6	1930	XIV	1–12	1940	XXIV	2–12
1922	VI	3–6	1931	XV	1–12	1941	XXV	12
1923	VII	1	1932	XVI	1–5, 7, 9–12	1942	XXVI	3, 5–12
1924	VIII	1, 4–6	1933	XVII	1–3	1943	XXVII	1, 4–12
1926	X	5, 7–10	1934	XVIII	9–12	1944	XXVIII	2–12
1927	XI	6, 9, 11	1937	XXI	9, 11, 12	1945	XXIX	1–12
1928	XII	6–12	1938	XXII	1, 2, 4, 5, 7, 9–11			
1929	XIII	1–12	1939	XXIII	1–12			

BULLETINS AVAILABLE (1946–1949) SINCE COMPILATION OF COMPREHENSIVE INDEX ANNUAL CONTENTS INDEXED IN EACH DECEMBER NUMBER

1946 VOL. XXX.—2120 pp....................Each number (To members, $1.00) $1.50

NO. 1—156 pp. CALIF.: Los Banos district, San Joaquin Valley. E. INDIES: Basins; reef corals. GEN.: Hydrocarbons, slumping; conodonts; classification of possibilities; multiple sands. TEX.: Waller and Harris Cos.; Devonian, TXL pool, Ector Co.

NO. 2—148 pp. ALA.: Pre-Selma Cretaceous. ALBERTA: Jurassic-Cretaceous. GEN.: Continental shelves. MONT.: Jurassic-Cretaceous. ORE.: Up. Nehalem River. PERU: Reconnaissance. TEX.: Katy field, Waller Co.; Low. Pennsylvanian.

NO. 3—172 pp. ECUADOR: Up. Cretaceous and Paleocene micropaleontology. EUROPE: Carpathian oil fields. GEN.: Porosity through dolomitization; members; financial. NEBR.: Boice shale, Mississippian. WEST VA.: Drill cuttings.

NO. 5—168 pp. ALA.: Vick formation. GEN.: Organic material; Jacob staff; aerial photog.; minutes; college students. KAN.: Buried hills, Barton Co.

NO. 6—264 pp. DEVELOPMENTS. PERU: Geol. TURKEY: Harbolite.

NO. 7—144 pp. GEN.: Science legislation; military service; production engineering; grain roundness. TEX.: Gas reserves; Quaternary. VA.-TENN.: Ordovician.

NO. 8—212 pp. GEN.: Geological directory. KAN.: Siluro-Devonian. MONT.: Ellis, Amsden, Big Snowy group, Judith basin. UTAH: Paleozoic-Mesozoic, Uinta Mtns.

NO. 9—188 pp. ALASKA: Possibilities. FRANCE: Aquitaine basin. GEN.: Quimbys Mill member, Platteville formation, Ordovician; oölite and oölith. GERMANY: Oil fields. S. AMER.: NW. framework. UNITED KINGDOM: Occurrence of oil.

NO. 11—184 pp. ARIZ.: Faulting, Grand Canyon. GEN.: Faults; spectrochemical logging; grain size; Jacob staff; organic material. N. MEX-W. TEX.: Permian. N. CAR.: Continental slope. OKLA.: W. Edmond. TEX.: Hawkins, Wood Co.

NO. 12—140 pp. GEN.: Oceans and continents; geological-geophysical trends; drilling statistics. OKLA.: Elmore embayment, Garvin Co. S. AMER.: Framework.

1947 VOL. XXXI.—2268 pp. . . . . Each number (To members, **$1.00**) **$1.50**

NO. 1—200 pp. AUSTRALIA: Stratigraphy. CANADA: Ordovician, Silurian, Yukon Ter. CUBA: Camaguey dist. GEN.: Stratigraphy, sedimentation. JAPAN: Production. KAN.: Kinderhook dolomite, Sedgwick Co. KAN.-OKLA.: Oil and stratigraphy.

NO. 2—228 pp. ARIZ.: Paleozoic. CALIF.: Fish remains. GEN.: Vertical scale; log map; resistivity and core analysis; altimeter surveying, reservoir fluids. GULF: Diastrophism. MICH.: Cambrian, Ordovician in deep wells. S. DAK.: Jurassic, Black Hills. TEX.: Analyses of basal complex. WYO.: Black Hills; Paleozoic, Park Co.

NO. 3—228 pp. GEN.: Basin structures; aerial photos; diagenesis and weathering; sedimentology; stratigraphic commission; members; audit. MICH.: Traverse group. N. MEX.-TEX.: Permian Castile sea. TEX.: S. Mayes, Chambers Co.

NO. 4—140 pp. GEN.: Continental shelves; evolution of geologic thought; Permian correlations; facies map, log map. GULF COAST: Tertiary; micropaleontology. N. MEX.: Rattlesnake field, San Juan Co. TEX.: Del Monte field, Zavala Co.

NO. 5—120 pp. GEN.: Photogeology in Naval exploration; annual reports and minutes.

NO. 6—264 pp. ANNUAL DEVELOPMENTS.

NO. 7—232 pp. GEN.: Presidential addresses; domestic and foreign development; salt-dome structure; nomenclature; oceans and continents. KAN.: Ordovician limestones.

NO. 8—196 pp. AUSTRALIA: Roma. CALIF.: Ventura Basin. COLO.: Up. Montana group. GEN.: Insoluble residue; clay mineralogy; plane-table; glauconite. MONT.: Devonian. N. MEX.: Comanche, Black R. Valley. PACIFIC: Production. RUSSIA: Reserves. TURKEY: Paleozoic-Mesozoic. WYO.: Oregon Basin.

NO. 9—172 pp. BRIT. COLUM.: Mississippian. CALIF.: Salt Creek. GEN.: Faults. KAN.: Up. Ordovician LA.: Tidal basins. N. MEX.: Triassic, Pecos Valley. ROCKY MTNS.: Jurassic. TEX.: Tidal basins. WYO.: Paleozoic and Mesozoic.

NO. 10—204 pp. ALA.: Black Warrior Basin. COLO.: Freezeout Creek fault, Baca Co. FLA.: Oil. GEN.: Microbial transformation; geomorphology; Cretaceous, SE. U.S.; onlap and strike-overlap; dip computation; perspective diagrams. GULF COAST: Cenozoic. MISS.: Black Warrior Basin. OKINAWA: Geology.

NO. 11—176 pp. CALIF.: Sespe redbeds. COLO.: Pennsylvanian. GEN.: Convergence; diagenesis of brines; steeply dipping oil sands; pore space; Foraminifera. GERMANY: Hannover conference. LA.: Crowville dome, Franklin Parish. N. CAR.: Coastal Plain. TEX.: Ellenburger, Llano Co.; Saratoga salt dome, Hardin Co.

NO. 12—180 pp. GEN.: Carbon-ratio; salt-dolomite intergrowths; annual index. VENEZUELA: Greater Oficina, West Buchivacoa, El Mene de Acosta fields.

1948 VOL. XXXII.—2370 pp. . . . . Each number (To members, **$1.00**) **$1.50**

WHOLE VOLUME: Bound in two parts. Cloth . . . . (To members, **$6.00**) **$17.00**

NO. 2—164 pp. FRANCE: Gas structures. GEN.: Sedimentation and accumulation; core orientation. SIBERIA: Oil. TEX.: Slick-Wilcox field, DeWitt and Goliad Cos. VENEZ.: Maracaibo Basin.

NO. 3—200 pp. GEN.: Stratigraphic commission; members; audit. MO.: Plattin-Joachim zones. U.S.S.R.: Petroliferous provinces.

NO. 4—192 pp. GEN.: Transferring distances on maps of different scale. MICH.: Mississippian Marshall formation. VENEZ.: Oil fields of Royal Dutch-Shell.

NO. 5—142 pp. BAHAMAS: Submarine features. COLO.-KAN.-OKLA.: Hugoton embayment. GEN.: Appal. and Alpine structures. ILL.: Benton field, Franklin Co. MEX.: Ranger Bank. ORE.: Siletz R. volcanics. TENN.: Up. Devonian bentonite. TEX.: Petersburg pool, Hale Co.

NO. 7—184 pp. CAL.: Fractured rock reservoirs. GEN.: Presidential addresses; petroleum in E.R.P.; isopachous maps of sands; geology, 1907–47; survey of students. GULF: Artesian salt. N. D.: Sentinel Butte sh.: OKLA.: Up. Cambrian. W. INDIES: Tertiary Cipero marl; Curacao.

NO. 8—296 pp. APPALACHIAN BASIN Ordovician symposium. CAL.: Ramona field, Los Angeles and Ventura Cos.

NO. 9—160 pp. GEN.: Geologist in uniform; structure and fault systems, East. Interior; gas for future LA.: W. Tepetate field, Jeff. Davis Parish. MEX.: Jurassic; Santa Rosalia, Baja Calif.

NO. 11—172 pp. GEN.: Geologic tools. ILL.: Deep drilling. KY.: Hitesville Consolidated field, Union Co. MID.-CONT.: Pennsylvanian. ROCKY MTNS.: Red-banded Cenozoic.

NO. 12—188 pp. CALIF.: Salinas Valley. GEN.: Catalysts in formation of oil; template for spacing contours; scientists and reserve officers; annual index. LA.: Submarine canyon. OKLA.: Fernvale and Viola.

1949 VOL. XXXIII.................................Each number (To members, $1.00) $1.50

WHOLE VOLUME: Bound in two parts. Cloth.......................(To members, $10.00) $17.00

NO. 1—130 pp. ASSAM: Digboi field. CALIF.: Santa Maria fractured reservoirs. COLO.: Lyons sandstone. GEN.: Sampling and examination of well cuttings; oscillation chart; origin of oil.

NO. 2—144 pp. BRIT. COLUM.: Paleozoic, Alaska Highway. KAN.-OKLA.: Subsurface sections, Marion Co. to Osage Co. ONTARIO: Salina-Guelph fields. PANAMA: Tertiary.

NO. 3—212 pp. GEN.: Pennsylvanian divisions; membership; audit. N.Y.-PA.: Oriskany gas. W. VA.: Stratigraphic accumulation, Jackson-Kanawha Cos.

NO. 4—168 pp. ALBERTA: Basin symposium. GEN.: Onlap, offlap, overstep, overlap.

NO. 5—128 pp. COLO.-UTAH: Green and Yampa R. canyons, Dinosaur Natl. Monument. GEN.: Paleotectonic and paleogeologic maps, central and western N. America; pioneers in geology; annual reports and minutes. OKLA.: Structure, east flank Anadarko basin, Cleveland and McClain Cos.

NO. 6—342 pp. ANNUAL DEVELOPMENTS

NO. 7—184 pp. GEN.: Presidential addresses; tectonics of north-central U.S.; stratigraphic commission notes. GULF COAST: Photogeology. TEX.: Upper Jurassic in NE. Tex.; strand-line accumulation, Jim Hogg Co. UTAH: Paleozoic, Uinta basin.

NO. 8—156 pp. GEN.: Pioneer geologists. GULF COAST: Mesozoic igneous rocks. MEX.: Tectonics, oil fields. N. MEX.: Pliocene Ogallala algal limestone, Union Co.

NO. 9—168 pp. ALBERTA: Foothills structure. BRAZIL: Oil fields, oil-shale reserves. BRIT. COLUM.: Devonian and Mississippian, Wapiti Lake. CALIF.: Foraminifera of Franciscan. CHILE: Magallanes Province. GEN.: Active-surface catalysts in formation of petroleum; odometer mileage from road logs.

NO. 10— pp. APPALACHIANS: Structure; Greenbrier formation. GEN.: Origin of oil. KY.: Cambrian and Ordovician subsurface. OHIO: Mayfield pool, Cuyahoga Co. PA.: Upper Devonian subsurface; aeromagnetic survey, Clearfield-Philipsburg area.

NO. 11— pp. GEN.: Sedimentary tectonics and environments; connate-water resistivity from self potential log data. TEX.: Grand Saline salt dome, Van Zandt Co.; Frio formation, Orange and Jefferson Cos.

NO. 12— pp. COLO.: Pierre formation. GEN.: Annual index. GULF COAST: Sedimentary facies. WYO.: Oil in Cambrian, Lost Soldier field, Carbon and Sweetwater Cos.

1950 VOL. XXXIV.................................Each number (To members, $1.00) $1.50

WHOLE VOLUME: Bound in two parts. Cloth.......................(To Members, $10.00) $17.00

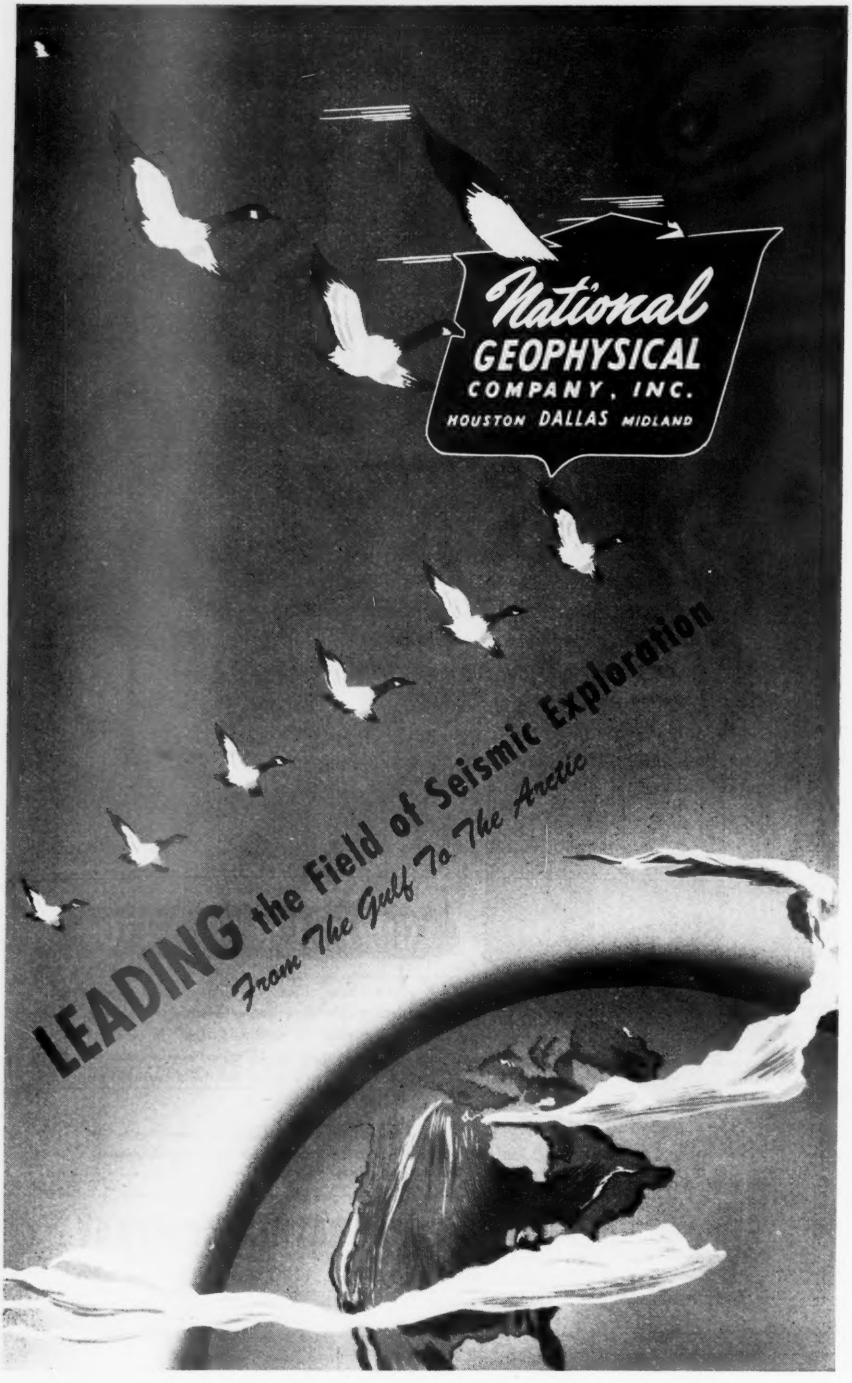
NO. 1— pp. ATLANTIC COASTAL PLAIN (N.J., DEL., MD., VA.): Cretaceous and Tertiary. N. CAR.: Subsurface.

NO. 2— pp. SYMPOSIUM ON REEFS. ALBERTA: Devonian reef, Leduc field. GEN.: Definition, geologic, recent, transgressive, regressive. MIDDLE EAST: Cretaceous and Tertiary reefs. TEX.: Pennsylvanian reef, Todd field, Crockett Co.

SPECIAL SUGGESTIONS

1. **Directory of Films and Slides of Possible Interest to Geologists** will be mailed free upon request. 22 pp.
2. **Directory of Geology Departments of Educational Institutions in the United States and Canada** is ready: information for students, teachers, and companies planning geology personnel. 136 pp. $1.50.
3. **Problems of Petroleum Geology** has been reprinted and bound in cloth. 1,073 pp., 200 illus. $4.00 to members; $5.00 to non-members.
4. **Stratigraphy of Plains of Southern Alberta** is still available and helpful in exploration in Canada. October, 1931, *Bulletin*. 166 pp., 60 illus. $1.00 to members; $1.50 to non-members.

MONOCLINE MAC and GOSSAN GUS Say:
Expedite Field Work,
Accelerate Interpretations with
GEOLOGICAL INSTRUMENTS FOR-
TOMORROW'S TECHNIQUES
10X TRIPLET
Here's exceptional width of flat, color-free field—It's MOHAVE'S Hastings Triplet, 10X. Ultra-modern styling, gleaming stainless steel frame for brute service wherever the search for minerals goes on. Wave-length accuracy in flawless optical elements designed for basic research—corundum finished cell—mean lifetime performance for either professional or student!
$12.00
Penscope* Six, the new field telescope for reconnaissance & scouting, saves miles, has amazing 315-foot field at 1000 yds. Six anti-glare lenses, lovely satin chrome & midnight jet housing, which snuggles into pocket like a superb pen, and 6X magnification, brings distant outcrops & contacts "home." Dandy for sports too!
$10.00
Photogeology in field or classroom is buttressed with MOHAVE'S folding, field stereoscope. Superb optics insure maximum depth-of-focus, stereo effect, for faint structural, physiographic, and cartographic detail. Finished in durable black, with sturdy leather case for shirt pocket. (Other photogrammetric & photogeologic instruments for any application—tell us your problem)
$10.00
Stratigraph gives you instant solutions to space problems involving variables of DIP, DISTANCE, DEPTH, TRUE or APPARENT THICKNESS. For fault and section computations, preparation of structural contour and ore-reserve maps, and problems involving tedious descriptive geometry. Precision cursor; cardinal & jet lines on pearly background. With case and directions. (See Bull. AAPG, Vol. 26, No. 6, 1942, & Journal of Geology, Vol. 57, No. 3, 1949)
$5.00
←Core & Crystal Goniometer pays for dip measurements in cores, drill orientation, crystallography. 2 scales (0 thru origin is strike) give direct readings, eliminate bothersome subtractions. Graduations to ½ degree are protected against wear by laminating in sheer vinylite. Indispensable for drilling, boring, core or crystal determinations.
$3.25
The Field Bag that has everything! 2 scale, 6 pencil pouches for convenience. Ample space for lunch, maps, camera, field book & samples. Will accommodate 9" x 12" aluminum sheet holder (optional at $2.50) for photogeology, dip determinations, underground mapping. Water-repellent O.D. duck, rain flaps, sturdy hardware and shoulder strap. You'll find MOHAVE field bags wherever there's exploration!
$10.00
* T.M. Reg. Prop. of Pantechnics, Ltd.
Other Mohave Geological Specialties—Ainsworth Bruntons, Ultraviolet Lamps for minerals & hydrocarbons in various A.U. ranges, radiation detectors, gold pans, pocket microscopes 10X to 40X, mineralogy equipment. Write for literature.
DESIGNED, BUILT, AND IN WORLDWIDE SERVICE BY TOP-FLIGHT GEOLOGISTS!
BUY THEM NOW from better instrument dealers in principal cities. Factory shipments if no dealer near you.
Washington, D.C., Distributors—KINSMAN OPTICAL CO.
MOHAVE INSTRUMENT CO.
1861 HILLHURST AVE.
Dept.17
LOS ANGELES 27 CAL.


National
GEOPHYSICAL
COMPANY, INC.
HOUSTON DALLAS MIDLAND
LEADING the Field of Seismic Exploration
From The Gulf To The Arctic